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AERONAUTICAL ENGINEERING REVIEW

INSTITUTE OF THE AERONAUTICAL SCIENCES

OCTOBER 1952

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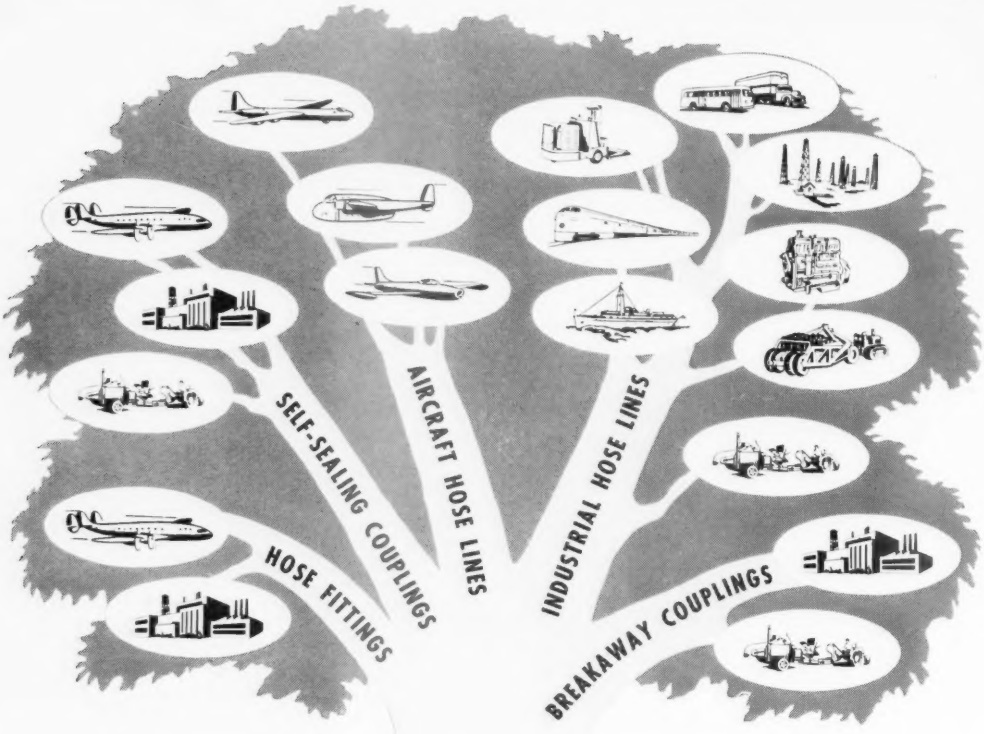

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Cover—An F-89D Scorpion, built by Northrop Aircraft, Inc., shows its "grand slam" sting as it salvos clusters of 2.75-in. FFAR air-to-air rockets from its wing-tip pods during recent armament tests over the southern California desert. This all-weather fighter is equipped with electronic aiming and automatic triggering devices that permit the pilot to direct his fire with "pin-point accuracy." The rockets replace the six 20-mm. cannon carried by earlier F-89 models. The "D" is powered with twin Allison J-35 jet engines.

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AERONAUTICAL ENGINEERING REVIEW

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I. A. S. News

A Record of People and Events of Interest to Institute Members

Air-Line Official to Deliver 1952 Wright Brothers Lecture

William Littlewood, American Airlines' Vice-President—Engineering, Selected as Wright Brothers Lecturer

William Littlewood

THE SIXTEENTH PRESENTATION of the Wright Brothers Lecture will be given this coming December 17 by William Littlewood, Vice-President—Engineering of American Airlines, Inc. This delivery, which marks the forty-ninth anniversary of man's first free, controlled, and sustained flight of a power-driven, heavier-than-air machine by Orville and Wilbur Wright, will take place in the U.S. Chamber of Commerce Building Auditorium in Washington, D.C. All I.A.S. members and their guests are cordially invited to attend.

Mr. Littlewood's subject on this occasion will be "Technical Trends in Air Transportation." In this lecture, he proposes to discuss some of the current engineering problems of air transportation and their present state of solution—satisfactory or otherwise. He also proposes a forecast of indicated trends with respect to types, sizes, performances, economics, and other basic equipment and operation factors deemed to affect the growth and prosperity of air transportation.

Mr. Littlewood is a product of the Empire State. He was born in New York City on October 21, 1898. He attended Long Island grammar and high schools and Heffley Institute, and in 1916 he matriculated at Cornell University. As a Cornell undergraduate, he assisted on the staffs of the physics, mechanics, and machine design departments and was awarded the Sibley Prize for 2 consecutive years for holding the highest rating in engineering studies. He was graduated from Cornell in 1920 with a degree in Mechanical Engineering.

Within a short time of his graduation from college, he secured a position as Assistant Shop Superintendent for the Ponds Works of Niles-Bement-Pond Company. He left Niles-Bement-Pond in 1924 to become Assistant Superintendent for Ingersoll-Rand Company. In both of these positions, he was in charge of jig and tool design and construction, production and shop methods maintenance of plant and equipment, and inspection standards and methods.

Mr. Littlewood first became allied with the aircraft industry in 1927 when he joined the staff of Fairchild-Caminez Engineering Corporation as Production Manager. The following year, he became General Manager of Fairchild Engine Company. During this period, he was instrumental in developing several aircraft engines that were then regarded as among the best. At this time, he also visited Europe and acquired a comprehensive knowledge of continental aircraft plants.

His present affiliation with American Airlines began in June of 1930, at which time he joined the predecessor company, American Airways, Inc. He was promoted to the position of Chief Engineer in 1933. The company was reorganized in 1934, and 3 years later he was elected Vice-President—Engineering.

The work that Mr. Littlewood has accomplished in the development of such aircraft as the Douglas DC-3, DC-4, and DC-6 and the Convair 240 has received recognition on both sides of the Atlantic. It's interesting to note at this juncture that several years ago the British aviation magazine, *The Aeroplane*, stated that "the industry has Littlewood's genius to thank for much of the efficiency built into the aircraft that really put the air transport business on the map.

"The results of Littlewood's 20 years' work for American Airlines provide the most convincing and tangible evidence that the best transport vehicles are those evolved in specification from the practical engineering experience of the operator; always provided that the air-line engineer has the necessary spark of genius, and above all knows what he wants."

Mr. Littlewood is a Director of Cornell Aeronautical Laboratory, Inc., and a Vice-Chairman of the National Advisory Committee for Aeronautics. An I.A.S. Fellow and past-officer, he also belongs to the American Society of Mechanical Engineers and the Society of Automotive Engineers.

The Wright Brothers Lecture, an annual I.A.S. feature, is endowed by The Vernon Lynch Fund and was established in 1937.

1952 Guggenheim Medalist

Sir Geoffrey de Havilland

For "forty years of pioneering in military and commercial aircraft and the development of long-range jet transport."

Sir Geoffrey de Havilland, Technical Director, The de Havilland Company, Ltd., of England, has been selected as the recipient of the Daniel Guggenheim Medal for 1952. Sir Geoffrey was cited for "forty years of pioneering in military and commercial aircraft and the development of long-range jet transport." Presentation of the award will take place during the Annual Meeting of The American Society of Mechanical Engineers to be held in New York's Hotel Statler from November 30 to December 5.

This year's Board of Awards was composed of 21 persons who are either past winners of this award residing within the United States or representatives of the A.S.M.E., Institute of the Aeronautical Sciences, and Society of Automotive Engineers. Sir Geoffrey received the unanimous vote of this group.

▶ **The Medalist**—Sir Geoffrey received his education at St. Edward's in Oxford and at the Crystal Palace School of Engineering. In the early 1900's, he was employed in the drawing offices of Wolseley Motor Company, Vanguard Motor Bus Company, and London General Motor Bus Company—all British firms.

His career in aeronautics, which led to his being knighted by King George VI in 1944, began in 1909 when he first designed aircraft and their engines. On February 7, 1911, he qualified for the Royal Flying Corps brevet, No. 53, flying a biplane of his own construction. That same year, he joined the staff of the Royal Aircraft Factory, Farnborough, as a Designer and Pilot. Three years later, he became associated with Aircraft Manufacturing Company as Chief Designer; he remained there for the duration of World War I. He formed his own company in 1920.

Throughout his career, Sir Geoffrey has been responsible for the designs of many production aircraft, both past and present.

An I.A.S. Honorary Fellow and Founder Member, Sir Geoffrey is also a Commander of the Order of the British Empire and a Fellow of the Royal Aeronautical Society.

Aeronautical Structures Laboratory at Columbia

Plans for an Aeronautical Structures Laboratory at Columbia University's new Engineering Center have been announced by Dr. John R. Dunning, Dean of the Columbia School of Engineering.

The laboratory will have two prime functions: (1) It will act as a focal point in the development of structures for high-velocity aircraft and multiple-step transoceanic rockets. (2) It will serve as a central source for research information in the field. In carrying out these functions, the laboratory will be able to provide industry with trained specialists in the aeronautical structures field.

Among the problems to be investigated by the new laboratory will be ones such as adapting aircraft structures to air-borne refueling procedures and to parasite aircraft techniques and exploring the structural modifications required for aircraft using radioactive material or equipment.

The second function of the laboratory will be performed by a Research Information Exchange program. This information section will serve as a clearing-house for long-range basic-research data on aircraft structures, rockets, and guided missiles.

The information section will make a critical survey of existing research literature on aeronautical structures and materials; attempting to summarize whatever is of permanent value to the industry or educational groups. It will also keep in contact with research in progress and maintain close liaison with industry so that future research problems may follow the most practical line. In this way, it may be possible to reduce substantially the time lag between the development of new construction techniques and their application by the designing engineer.

The Columbia engineering faculty will form the nucleus of the new Aeronautical Structures Laboratory. The following faculty members will contribute to the laboratory program: H. H. Bleich; Dr. Bruno Boley, M.I.A.S.; Alfred M. Freudenthal, M.I.A.S.; J. M. Garrelts; Raymond D. Mindlin; and Mario G. Salvadori. Dr. Boley came to Columbia University from The Ohio State University this past September.

Columbia also plans to establish an advisory committee of prominent engineers from the aircraft industry to work closely with the research and teaching staff.

The university's special facilities, including the Materials Testing Laboratory, Analogue and Digital Computers, and Cyclotron at Irvington-on-Hudson,

(*Continued on page 64*)

Necrology

Follett Bradley

Major General Follett Bradley, U.S.A.F. (Ret.), M.I.A.S., died on August 4 of a heart attack in a Mineola, L.I., N.Y., hospital. He was 62 years old.

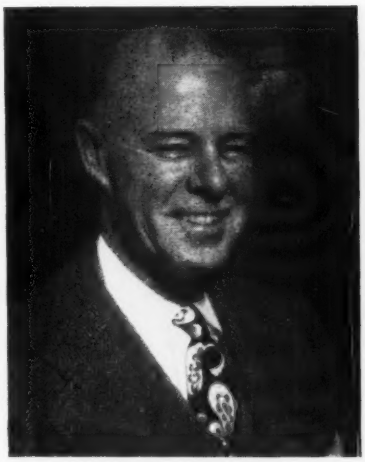
General Bradley, a native of Nebraska, was a Midshipman in the U.S. Naval Academy from 1906 to 1910. After serving as an Ensign for 2 years, he transferred to the U.S. Army Field Artillery as a Second Lieutenant. Assigned to Ordnance in 1914, he served under the Air Commander of the American Expeditionary Forces during World War I on matters pertaining to aircraft armament and aerial gunnery. He was promoted to Major in the Air Service in 1920. He rose steadily through the commissioned grades and in February, 1942, was appointed a Major General. Shortly after the United States entered World War II, General Bradley was made Commanding General of the First Air Force. In July of 1942, he was sent on a special mission to Russia by the late President F. D. Roosevelt and was given the personal rank of minister. He was later awarded the Distinguished Service Medal for his services to the allied cause during this Russian assignment. During his military career, he also received the Silver Star, the Distinguished Flying Cross, and the Croix de Guerre with palm and bronze star.

General Bradley attended various service schools, including the U.S. Army Ordnance School of Application in 1915, the Air Service Engineering School in 1922, the Air Corps Tactical School in 1927, the Command and General Staff School in 1928, the Army War College in 1932, and the Navy War College in 1933.

Since his retirement from the Army Air Force in April of 1944, General Bradley had been Assistant to the President of Sperry Gyroscope Company, Division of The Sperry Corporation, in addition to serving as Aviation Coordinator for the company.

General Bradley was a member of the Wings Club, the Meadowbrook Club, the Garden City Golf Club, and the Army and Navy Country Club of Washington.

He is survived by his wife, Mrs. Hester Henderson Foster Bradley, two daughters, and seven grandchildren.



Major General Follett Bradley

E. W. ("Pop") Cleveland

E. W. ("Pop") Cleveland

Ephraim Watkins ("Pop") Cleveland was killed on August 7 when the Beechcraft Bonanza that he was piloting on a vacation trip crashed and burned near Mt. Baldy, some 30 miles southeast of Seattle, Wash. He was accompanied by his wife, Mrs. Lucille Wilkinson Cleveland, and his secretary, Mrs. Anna Belle Kron Elmslie, both of whom were killed in the accident.

Born 62 years ago in Naples, N.Y., Mr. Cleveland had logged approximately 10,000 hours since his first solo flight at Hammondsport, N.Y., in June, 1911. The year before this solo flight, he had gone to work for Curtiss Aeroplane Company as a mechanic and 5 years later worked for a short time as an engine builder for Wright Martin Company. From 1915 to 1919, he served as a mechanic and flight instructor for the Aviation Section of the U.S. Army Signal Corps.

When World War I came to an end, Mr. Cleveland purchased a war-surplus Jenny and for some years barnstormed around the country. In 1923, he accepted the position as Manager of Mayer Aircraft Company and 4 years later joined The Cleveland Pneumatic Tool Company, of which he was Vice-President and Special Sales Representative at the time of his death. He was also President of Aero Engineering, Inc., which he founded in March, 1941, and Vice-President and Director of Electronic Research Corporation and had been Vice-President of Airframe Supply Company since 1947 and Treasurer of Air Cruisers, Inc., since 1949.

Mr. Cleveland was in charge of the development of landing gears for the Douglas B-19 and the Convair B-36. In the period between September, 1939, and October, 1942, he was granted six patents on landing-gear devices for aircraft.

An Associate Fellow and Founder Member of the Institute of the Aeronautical Sciences, Mr. Cleveland served this past year as Chairman of the I.A.S. Cleveland-Akron Section. He was also a member of the Society of Automotive Engineers, Quiet Birdman, Cleveland Ad Club, Wings Club, City Club, Shrine Club, and various other organizations. During his career in aviation, which he once said he began because in 1910 it was "a brand new means of transportation with a future that very few people believed in," Mr. Cleveland led air tours around the country and officiated at major aeronautical events.

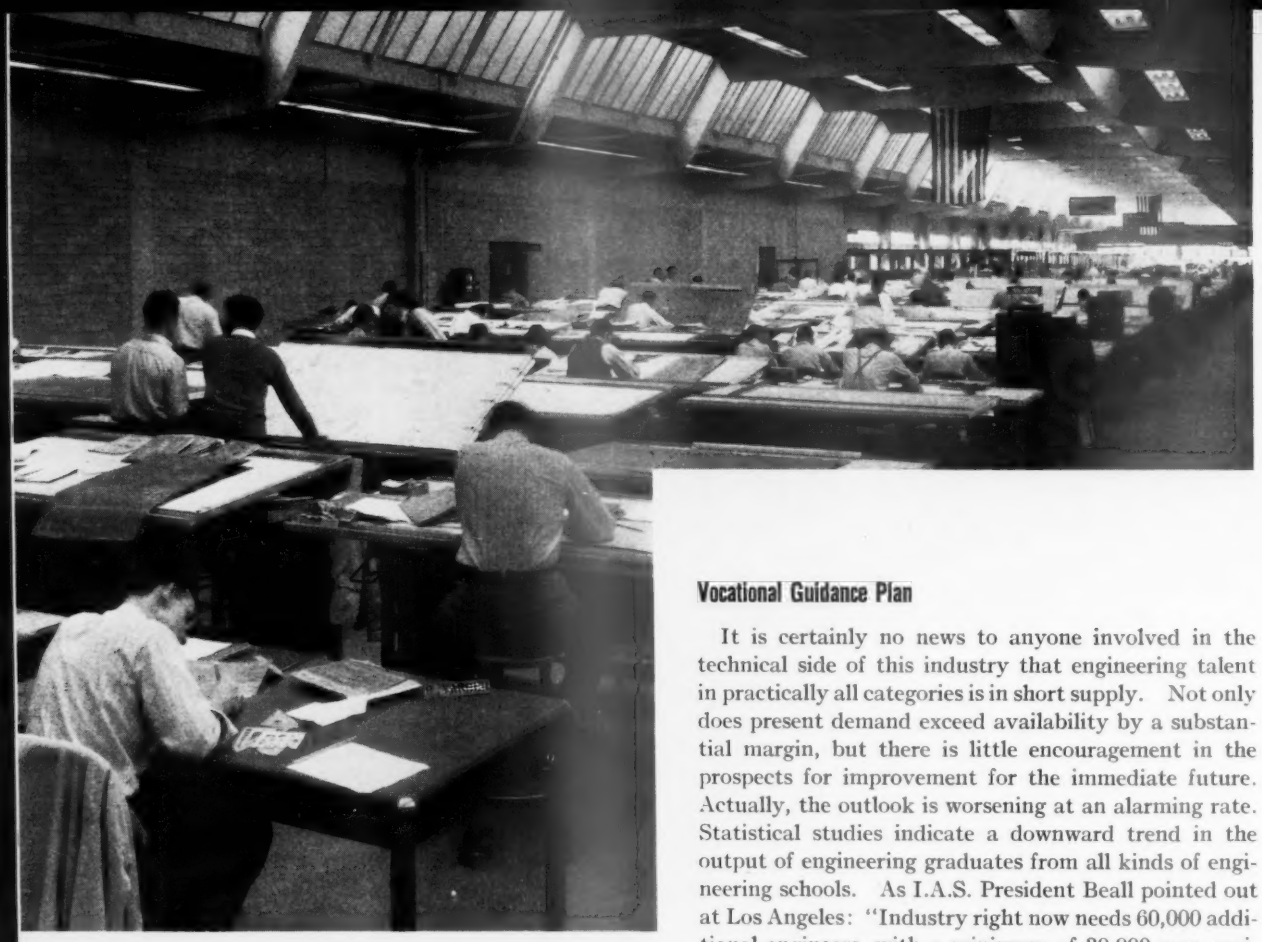
He is survived by his son, Lewis F. Cleveland.

James A. Wright

Word has been received concerning the death of James A. Wright, T.M.I.A.S. However, the date and the circumstances under which death occurred were not given.

Mr. Wright was born in Milwaukee, Wis., on October 4, 1926. He attended Milwaukee's Washington High School from 1940 to 1944 and was a student at Northrop Aeronautical Institute from January, 1949, until December, 1950.

Mr. Wright went to work for Hughes Aircraft Company the following month as a draftsman for various missile component installations and structures. He left Hughes' employment in September, 1951.



Editorial

Vocational Guidance Plan

It is certainly no news to anyone involved in the technical side of this industry that engineering talent in practically all categories is in short supply. Not only does present demand exceed availability by a substantial margin, but there is little encouragement in the prospects for improvement for the immediate future. Actually, the outlook is worsening at an alarming rate. Statistical studies indicate a downward trend in the output of engineering graduates from all kinds of engineering schools. As I.A.S. President Beall pointed out at Los Angeles: "Industry right now needs 60,000 additional engineers, with a minimum of 30,000 new engineers each year . . . look at the college and university picture . . . where 52,000 engineers were graduated in 1950 and only 38,000 in 1951, this year's total will be only 25,000," and the downward trend is continuing.

At the same time, President Beall mentioned that a project for the publication of an *I.A.S. Vocational Guidance Manual* was well under way. The plan is to publish a booklet designed to sell aeronautical engineering and the allied sciences to high-school graduates and to the freshman and sophomore groups in colleges and universities. The distribution of the booklet will be mainly via the Institute's 22 Sections and their associated 68 Student Branches in the United States.

Since July, with the active collaboration of a cross section of our Corporate Members, considerable progress has been made, and there is good reason to believe that the *I.A.S. Vocational Guidance Manual* will be available for distribution by the end of the year.

First and most important job was the compilation of a basic job classification list covering all engineering and

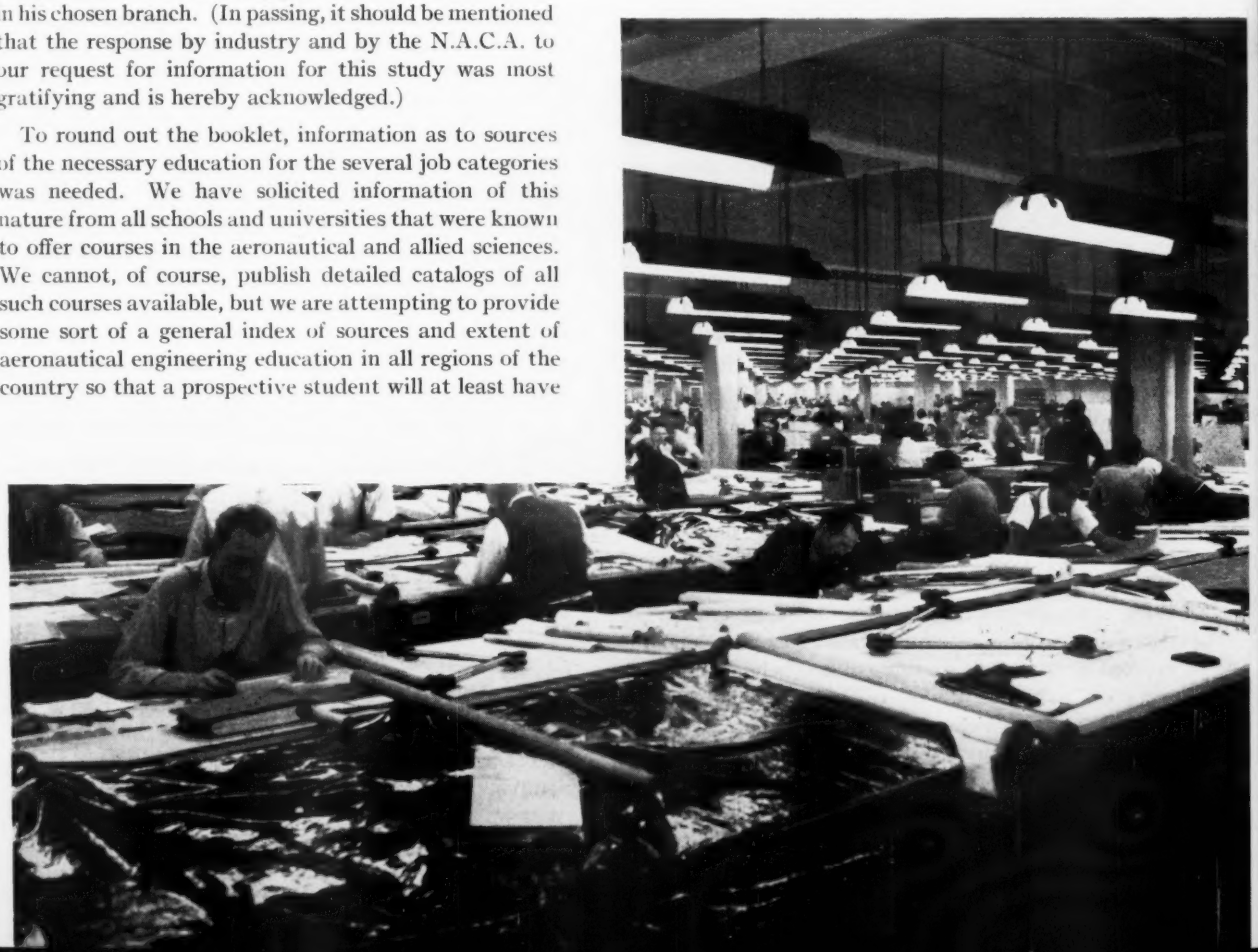
job and research activities in the aeronautical and allied professions. This in itself was no small task because of a certain lack of standardization of job definitions within the industry. Our staff finally boiled down the list to some 170 basic classifications, which seem to cover the field.

We then called upon industry for some advice and assistance. Blank forms were prepared listing our job classifications with space provided for the tabulation of certain basic information for each category—e.g., "What are the educational requirements for each job?"; "What practical experience?"; "What are the salary ranges?" etc. These questionnaires were sent to a selected group of our Corporate Membership, and the returns have been analyzed and tabulated. This study is the "heart" of the *Guidance Manual.* It spells out exactly What the Young Engineer Should Know in selecting a field for the exercise of his peculiar talents and is a yardstick for measuring potentials for advancement in his chosen branch. (In passing, it should be mentioned that the response by industry and by the N.A.C.A. to our request for information for this study was most gratifying and is hereby acknowledged.)

To round out the booklet, information as to sources of the necessary education for the several job categories was needed. We have solicited information of this nature from all schools and universities that were known to offer courses in the aeronautical and allied sciences. We cannot, of course, publish detailed catalogs of all such courses available, but we are attempting to provide some sort of a general index of sources and extent of aeronautical engineering education in all regions of the country so that a prospective student will at least have some sort of directory at hand to guide his own inquiries.

We are all aware that the publication of an *I.A.S. Vocational Guidance Manual* will not solve the problem of the engineering shortage. That is a long-range problem that will take many years to relieve. One essential, of course, is a reasonably stable industry that will automatically attract the right kind of talent from among the ranks of high-school graduates. There is a great deal of active competition from other industries, and it must be admitted that this aviation business has been "de-glamorized" to a certain degree. We do not intend to try to "re-glamorize" aeronautical engineering by means of a manual, but we are hopeful that it will provide another tool to assist our industry to obtain the technical man power it needs so that it can successfully cope with the increasingly complex problems of maintaining our national security through Air Power.

S. P. J.



The Shock Ignition Engine

FRANK F. RAND, JR.*
General Electric Company

Introduction

THE BASIC IDEA OF THIS PAPER is the utilization of a shock wave of the right intensity as an ignition source in an engine similar to the present-day ram-jet engine. The main difference is the elimination of the igniter and the flameholder. The engine should not be considered the final or only form that may be developed. In general, this method of ignition could be employed in either a steady or an unsteady flow cycle. This paper presents some of the salient features of shock ignition in a simple steady flow cycle.

Type of Combustion

The shock wave offers a different plateau for ignition than does normal deflagration. It is this plateau of ignition that enables the shock waves to ignite homogeneous fuel-air mixtures at much higher streaming velocities than does regular deflagration. This ignition wave could ignite fuel-air mixtures moving at a Mach Number as low as 1.8 and as high as 10.

Many men have been interested in the activated or disordered state of the molecules that exist through a shock wave. Becker, in his original work in 1922, calculated that the temperature in a shock wave traveling in air at 2,150 m. per sec. would be 2,260°K. Adiabatic compression to the same pressure that would exist behind a shock wave would only give a temperature of 794°K. The big difference is an indication of the disordered state of the molecules that exist behind the shock wave. It is this disordered activated state behind the shock wave that could be utilized to ignite homogeneous fuel-air mixtures. A. R. Ubbelohde of Belfast, Ireland, has attempted to explain theoretically what causes this form of ignition.

In ordinary deflagration the molecules are generally excited through the addition of heat to some activated state. The valance bonds are stretched until the molecules are in a position for combination with others. In the shock wave this is not necessarily done in the same manner.

In general, Ubbelohde and others believe there are three main contributing causes for shock ignition or detonation. First, as stated above, there is a high disordered state that exists through and behind the shock wave. This results in more collisions and more energy transfer between molecules. The second contributing cause is the great number of free atoms, molecules, and radicals that exist for combination immediately behind the shock front. Assuming a homogeneous mixture ahead of the wave, more combustion would be initiated in a short period than would be possible in normal deflagration. The third contributing cause is the high ordered motion that exists behind the shock wave. Behind a shock wave there is a streaming velocity in the direction of the shock-wave motion. This tends to cause more collisions in the direction of motion. Again, assuming a homogeneous mixture ahead of the shock, this would allow for more collision and more combination and, therefore, more heat release in the same time than would be the case in subsonic deflagration.

To bring out further the potential that exists through the action of shock waves, mention should be made of Dr. G. N. Patterson's work at the University of Toronto. Dr. Patterson and associates have designed a shock tube that will develop shock waves over a range of intensities. It has been demonstrated that shock waves could be focused and collided.

The group at the University of Toronto designed a double-ended shock tube to study this shock-wave interaction. Shock waves are simultaneously sent from opposite ends of the tube (Fig. 1). Exceedingly high temperatures may be developed when the waves collide in the center test section. In addition, they noticed that similar temperatures were created when a shock wave of the right intensity was reflected from a wall (Fig. 2). The *x-t* plot shows where the wave will be versus time in the tube. The temperature behind the reflected wave may be extremely high. This temperature only persists for a short period because of the action of the rarefaction wave that is following behind the shock. However, the temperatures are so extreme that the region behind the reflected wave may be luminous (Fig. 2, top picture). This tends again to point to the plateau that there is for ignition through the action of shock waves. It is conceivable that engines flying at lower supersonic Mach Numbers could employ this form of shock collision as an igniter and thereby eliminate the present spark source or igniter.

Past Experimental Evidence

In the past, many men have been interested in shock ignition or detonation, as it is commonly called. A distinction should be made between detonation and shock ignition. Shock ignition could be defined as an ignition wave that is overintense. Its intensity is controlled by conditions other than just the heat release. A detonation wave could be defined as a wave that

Presented at the Propulsion Session, Annual Summer Meeting, I.A.S., Los Angeles, July 16–18, 1952.

* Research Engineer. Now with the Scientific Laboratory of the Ford Motor Company.

progresses through a mixture at a speed dependent on the rate at which the heat is liberated behind it. Then, its steady-state Mach Number would be a function of the fuel and fuel-air mixture that is being used.

Detonation fronts have been investigated by men such as Chapman, 1899; Jouquet, 1905; and Becker, 1922. Using the equations of conservation of mass, momentum, and energy, these men predicted theoretical numbers for the steady-state detonation velocities. These theoretical predictions have resulted in good agreement with experimental detonations in tubes. More recently, Dr. W. C. F. Sheppard, of Sheffield, England, has investigated this form of ignition. He was interested in preventing mine explosions. Before his investigations had progressed very far, he had developed a shock tube and was sending shock waves into various fuel-air mixtures. They successfully ignited ethylene-air mixtures at temperatures as low as 704° to 726°R. Listed ignition temperatures were 1,464°R. This again tends to bring out the ignition potential that there is through action of a shock wave.

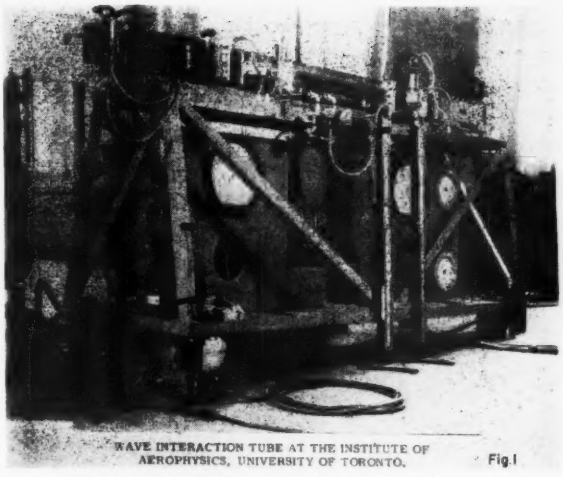
In addition to the work done by Dr. Sheppard, the University of Michigan in recent years has spent considerable time on this problem of detonation or shock ignition. This work was initiated in 1948 and has been continued to the present. In the early stages of this study, shock waves were produced by firing high-speed bullets into fuel-air mixtures. The nose (Fig. 6) was ground flat to produce a detached shock ahead of the bullet. The first tests were made with propane-air mixtures with no success. Following this, however, acetylene-air mixtures were used and were successfully ignited through the action of the normal shock at the nose of the bullet. These tests were summarized in progress reports published at the University of Michigan. The theoretical pressure and temperature as calculated from the following formulas gave the pressure behind the shock to be 225 lbs. per sq.in. absolute and the total temperature behind the shock to be 1,965°R.:

$$\frac{p_2}{p_1} = \frac{2\gamma M^2}{\gamma + 1} - \frac{\gamma - 1}{\gamma + 1} \qquad (1)$$

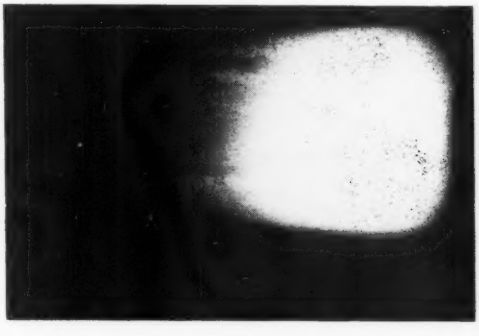
$$T_0 = T\left\{1 + [(\gamma - 1)/2]M^2\right\} \qquad (2)$$

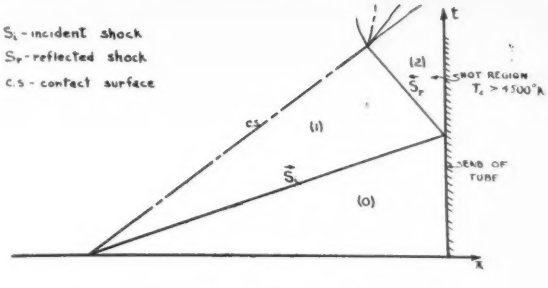
This assumed the ambient temperature of 540°R. and a γ of 1.4.

Following these bullet experiments, a shock tube was developed in order to give better control of the variables. The shock tube is not new. It was initially developed by Vieille in 1899, and the basic principles have not changed since the original. In general, there are three sections: the reservoir for storing the high pressure gas, the valve section, and the downstream test section. For the work at Michigan three assumptions were made: (1) The temperature was assumed to be the same in the reservoir and in the test section filled with fuel-air mixture before the diaphragm or valve was opened; (2) the diaphragm was assumed to shatter instantaneously; and (3) the flow was assumed to be one-dimensional through the tube.



WAVE INTERACTION TUBE AT THE INSTITUTE OF AEROPHYSICS, UNIVERSITY OF TORONTO. Fig.1





RADIATION PRODUCED IN A SHOCK TUBE BY REFLECTING A SHOCK WAVE FROM A RIGID WALL.

Fig.2

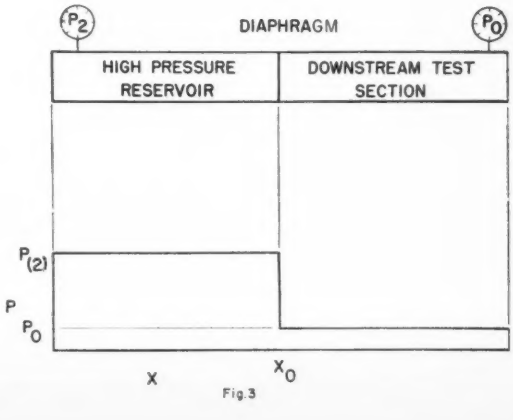


Fig.3

The reservoir gas that is stored under pressure forms a driving piston and moves downstream into the test section. This driving piston of reservoir gas produces the shock wave. By controlling the reservoir pressure and the downstream test section pressure before shattering the diaphragm, any desired Mach Number of shock wave can be formed. Fig. 3 shows the schematic drawing of the shock tube and the pressure distance plot before the diaphragm is shattered. P_2 and P_0 are the reservoir and test section pressures, respectively, before the diaphragm is shattered. When the diaphragm is shattered, the reservoir gas starts flowing downstream into the test section (Fig. 4). It is this driving piston of reservoir gas which produces the shock wave. The velocity and pressure are equal behind, and ahead of, the front face of the contact surface. See section (1) and (1)^1 of Fig. 4. T_1 is much hotter, however, than T_1'. As the front face of the driving piston, called contact surface, and the shock wave move downstream, a rarefaction wave moves upstream. The tube must be designed so that the shock wave can reach the test section before the rarefaction wave can go upstream to the end of the reservoir and back. The following expression gives the pressure ratio p_0/p_2 as a function of p_0/p_1 across the shock wave and the speed of sound A_2 and A_0:

$$\frac{p_0}{p_2} = \frac{p_0}{p_1}\left[1 - \frac{A_0}{A_2}\frac{(\gamma_2 - 1)}{2}\frac{\left(\frac{\gamma_0 + 1}{\gamma_0 - 1} - 1\right)\left(1 - \frac{p_0}{p_1}\right)}{\sqrt{\left(\frac{\gamma_0 + 1}{\gamma_0 - 1} + 1\right)\left(\frac{p_0}{p_1}\right)\left(\frac{\gamma_0 + 1}{\gamma_0 - 1} + \frac{p_0}{p_1}\right)}}\right]^{2\gamma_2/(\gamma_2 - 1)} \tag{3}$$

For the plot of p_0/p_2 and p_0/p_1 vs. Mach Number of the wave, see Fig. 5.

The operation of the shock tube then is quite simple. The desired Mach Number is obtained by setting P_0 and P_2. The desired fuel-air mixture is placed in the test section before the diaphragm is shattered. The distance between the front face of the reservoir gas and the shock wave becomes greater and greater as the shock wave and contact surface move toward the extreme downstream end of the test section. This enables the shock to ignite gases in a better fashion than could be done behind the bullet. This is one of the reasons why the bullet experiments were extended to the shock tube. It was felt that perhaps more time would be needed for the reaction rates to take place. A shock tube allowed more time and gave a constant set of conditions behind the shock wave and ahead of the driving piston of reservoir gas.

Figs. 7, 8, and 9 are typical acetylene-oxygen detonation pictures as taken in a shock tube at the University of Michigan. Fig. 7 is approximately a stoichiometric mixture. Fig. 8 is slightly leaner and Fig. 9 is the leanest. On scrutinizing these pictures it appeared that the leaner mixtures burned more roughly. Their ignition zone is somewhat thicker than would be the case for the near stoichiometric fuel oxygen mixture. Dr. R. B. Morrison, of the University of Michigan, has done considerable work in this field and has written his doctoral thesis on this phase of the investigation. These detonation pictures are part of that work that has been carried on during recent years. Fig. 10 shows two typical shock ignition pictures for hydrogen-oxygen mixtures. The leaner mixture appears to ignite downstream some distance from the shock front. Fig. 11 presents some of the data that have been collected at the University of Michigan. The shock tube described above was used for these experiments. It is clear that fuel-oxygen mixtures can be ignited over a range of Mach Numbers from $2 < M < 10$. The Mach Number of the detonation wave ap-

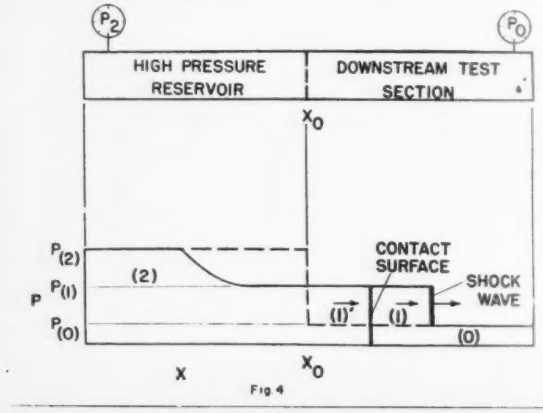


Fig. 4

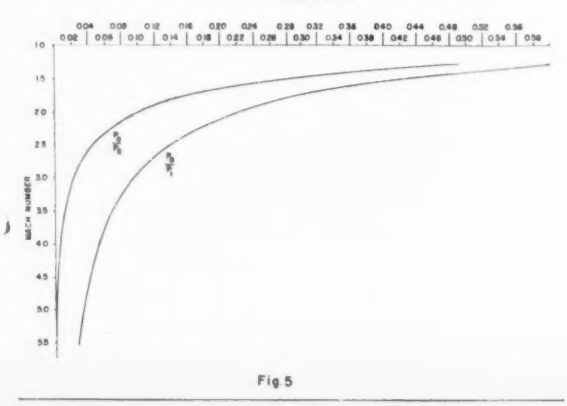


Fig. 5

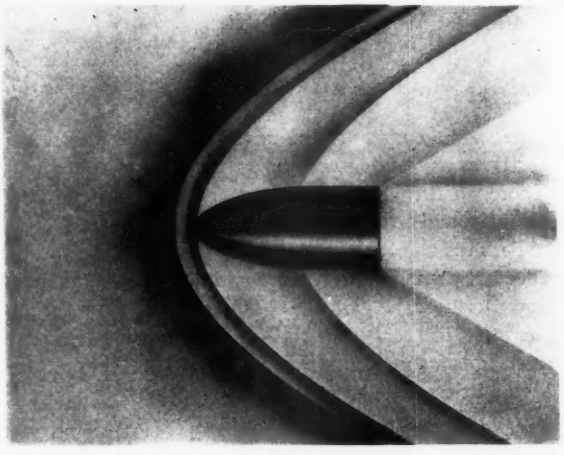


FIG. 6.

pears to be a function of the heat release behind and through the detonation front (Fig. 11). A report will be published at the University of Michigan summarizing this phase of the detonation study. From an investigation of these detonation waves and the above discussion, it is clear that a shock wave can be used to ignite various fuel-oxygen and fuel-air mixtures.

OUTSTANDING FEATURES

It appears that this form of ignition offers a different potential for ignition than does subsonic deflagration. It is not necessary to slow the incoming air down to a relatively low velocity in order to maintain combustion. In the past, the velocity in the combustion zone was of the order of 2 to 400 ft. per sec. Now, combustion chamber velocities could be as high as several thousand feet per second, depending on the selected fuel and the fuel-air mixture. This form of ignition can be used to ignite at temperatures that appear to be below those normally quoted for similar fuel-air mixtures. This is perhaps the result of the extreme activation state that exists behind the shock, as well as the high ordered motion and resulting collisions in the direction of shock motion.

THE ENGINE

Utilizing the above data, it appears that some form of engine could be designed to operate with this form of ignition. Fig. 12 presents such an engine. Fig. 13 presents the typical present-day ram-jet. The main difference, as mentioned before, is the elimination of the mechanical igniter and flameholder. The normal shock that exists in the downstream portion of the diffuser in the present-day ram-jet would be strengthened somewhat and utilized as a continuous ignition source.

The injection nozzles would be moved from the subsonic portion of the present-day ram-jet upstream to a position close to the diffuser throat. Injection would be such that mixing would take place upstream of the normal shock in the downstream portion of the inlet diffuser. Combustion or completion of combustion would take place within the constant area combustion chamber. The shock front itself would act as an infinite souce of pilot zones and combustion would be completed by the time the fuel-air mixture had reached the downstream end of the combustion region. The exit

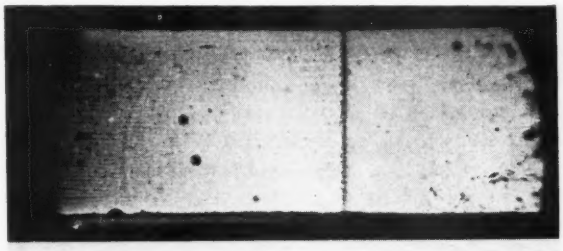


Fig. 7

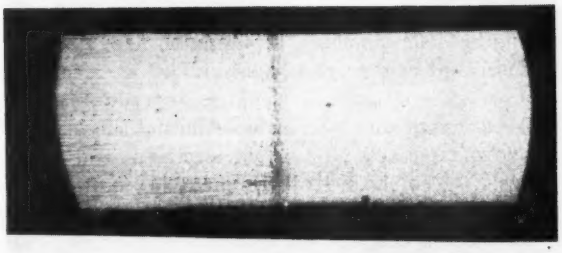


Fig. 8

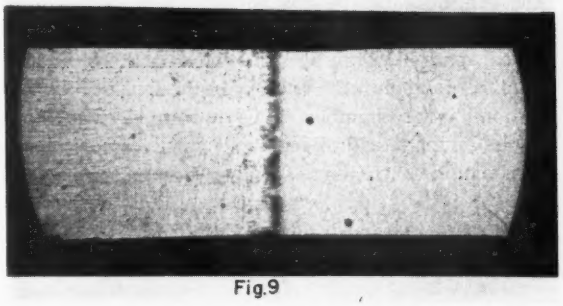
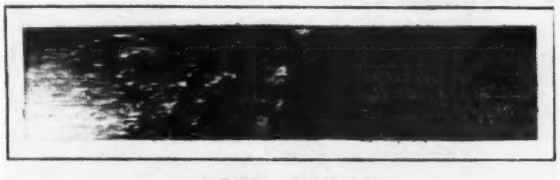
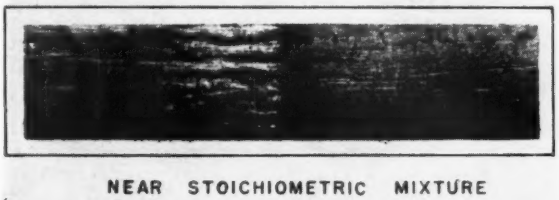


Fig. 9



LEAN MIXTURE
VELOCITY = 5500 FT/SEC



NEAR STOICHIOMETRIC MIXTURE
VELOCITY = 7500 FT/SEC

Fig. 10

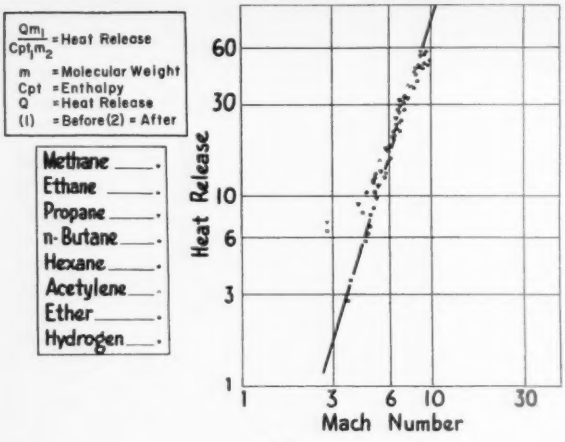


Fig. 11

nozzle would be used to control the location of the shock igniter. At the design Mach Number there would be a flow balance between the fixed geometry diffuser and exit nozzle shown in Fig. 12. Both the diffuser and exit nozzle would be operating at the correct design point. The stable normal shock igniter would be located near the downstream end of the diffuser. The shock position would be controlled by the critical mass flow through exit nozzle.

In other words, the throat of the exit nozzle is the controlling throttle for the mass flow through the engine. The location of the normal shock in the divergent portion of the inlet diffuser is controlled by this critical mass flow through the exit nozzle. This location is a function of the back pressure developed within the combustion chamber. The limiting mass flow for a Mach Number equal to 1 at the downstream exit nozzle throat could be written as follows:

$$m = \text{critical mass flow} = \rho A V \tag{4}$$

$$m_c = \rho A V = P_T A M \times \sqrt{\frac{\gamma}{RT_T}} \left[1 + \frac{\gamma - 1}{2} M^2\right]^{-(\gamma+1)/2(\gamma-1)}$$

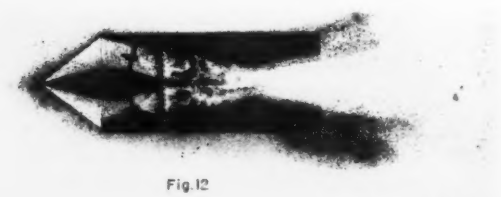


Fig. 12

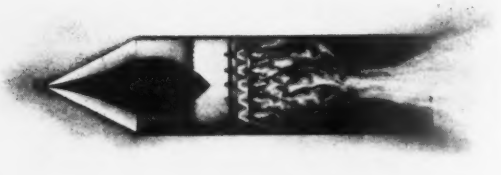


Fig. 13

For $M_4 = 1$,

$$m_c = P_T A \sqrt{\frac{\gamma}{RT_T}} \left[\frac{2}{\gamma + 1}\right]^{(\gamma+1)/2(\gamma-1)} \tag{5}$$

When A is constant, the critical mass flow varies directly as P_T and inversely as the square root of T_T. These, in turn, are dependent on flight velocity, fuel-air ratio, and altitude.

Perhaps a more complete way of expressing the balance between inlet and exit would be to equate the mass flow through the exit throat to the mass flow through the inlet diffuser. Let station 0 be that station at the inlet lip of the engine and station 4 be that station at the exit nozzle throat. If the fuel flow is neglected and if average γ's and R's are used, the continuity equation between stations 0 and 4 could be written as follows:

$$m = \rho A V \quad \text{continuity equation}$$
$$p = \rho R T \quad \text{state equation}$$

Therefore,

$$m = \rho A V = \frac{PAV}{RT} = \frac{PAV}{RT}\sqrt{\frac{\gamma RT}{\gamma RT}}$$

$$m = \frac{PAM}{RT}\sqrt{\gamma RT} = PAM\sqrt{\frac{\gamma}{RT}} \tag{6}$$

$$T = T_T/\{1 + [(\gamma - 1)/2]M^2\} \tag{7}$$

$$P = P_T/\{1 + [(\gamma - 1)/2]M^2\}^{\gamma/(\gamma-1)} \tag{8}$$

Substitute Eqs. (7) and (8) in Eq. (6).

$$m = P_T A M \sqrt{\frac{\gamma}{RT_T}}\left[1 + \frac{\gamma - 1}{2} M^2\right]^{-[\gamma/(\gamma+1)]+(1/2)}$$

$$m = P_T A M \sqrt{\frac{\gamma}{RT_T}}\left[1 + \frac{\gamma - 1}{2} M^2\right]^{-(\gamma+1)/2(\gamma-1)}$$

$$m_0 = m_4(1 - f)\,(w_f/g) \tag{9}$$

Neglecting fuel (f),

$$m_0 = m_4$$

$$\sqrt{\frac{\gamma}{RT_{T_0}}} P_{T_0} A_0 M_0 \left[1 + \frac{\gamma - 1}{2} M_0^2\right]^{-(\gamma+1)/2(\gamma-1)} = \sqrt{\frac{\gamma}{RT_{T_4}}} P_{T_4} A_4 M_4 \left[1 + \frac{\gamma - 1}{2} M_4^2\right]^{-(\gamma+1)/2(\gamma-1)}$$

Now $M_4 = 1$. Therefore,

$$\left(\frac{P_{T_4}}{P_{T_0}}\right)\left(\frac{A_4}{A_0}\right)\left(\frac{T_{T_0}}{T_{T_4}}\right)^{1/2} = M_0\left\{\frac{1 + [(\gamma - 1)/2]}{1 + [(\gamma - 1)/2]M_0^2}\right\}^{(\gamma+1)/2(\gamma-1)} \tag{10}$$

In order to gain a better understanding of the problem, assume for the moment that no heat is added to the air flowing through the duct. Therefore, after simplification, Eq. (10) could be written as follows:

$$\left(\frac{P_{T_4}}{P_{T_0}}\right)\left(\frac{A_4}{A_0}\right) = M_0 \left\{\frac{1 + [(\gamma - 1)/2]}{1 + [(\gamma - 1)/2]M_0^2}\right\}^{(\gamma+1)/2(\gamma-1)} \tag{11}$$

where $T_{T_8} = T_{T_4}$ and $M_4 = 1$.

Eq. (11) could be used to simulate conditions in a ram-jet engine employing shock ignition. The influence of back pressure on the mass flow pressure recovery and shock location can be studied. At the design point the shock is located in the divergent portion of the diffuser. Assume M_0 to be constant. Therefore, the right-hand side of Eq. (11) is constant. Increasing A_4 or the nozzle throat area would have to be balanced by decreasing P_{T_4}, since P_{T_0} on the right-hand side of the equation was held constant. Therefore, increasing A_4 would decrease the back pressure, and, for continuity to exist, the shock wave would have to move downstream in the diffuser. At this new position the normal shock would be stronger and P_{T_4} would decrease. Exactly the opposite would happen if A_4 were decreased. The back pressure would increase, forcing the shock to move upstream through the diffuser to a new position.

Actually, the back pressure in a jet engine employing shock ignition would be a function of the flight velocity, fuel-air ratio, and ambient temperature. A brief discussion of each variable would improve the understanding of the problem. Consider the effect of changing M_0 below the design point. Holding the altitude, ambient temperature, fuel-air ratio, and geometry constant, Eq. (10) could be rewritten as follows:

$$\frac{P_{T_4}}{P_{T_0}} = K\, M_0 \left\{\frac{1 + [(\gamma - 1)/2]}{1 + [(\gamma - 1)/2]\, M_0^2}\right\}^{(\gamma+1)/2(\gamma-1)} \tag{12}$$

where

$$K = (A_0/A_4)\left(\frac{T_{T_4}}{T_{T_8}}\right)^{1/2}$$

Decreasing M_0 would increase the right side of Eq. (12). Therefore, for the continuity equation to hold the ratio, (P_{T_4}/P_{T_8}) would have to increase. To do this, the shock wave must move forward toward the throat of the diffuser.

If all other variables were held constant except fuel-air ratio, only the design fuel-air ratio would give optimum performance and shock location. The effect of fuel-air ratio on the shock location could be studied if all of the other variables were held constant. Rewrite Eq. (10) as follows:

$$\left(\frac{P_{T_4}}{P_{T_0}}\right)\left(\frac{T_{T_0}}{T_{T_4}}\right)^{1/2} = \frac{A_8}{A_4} M_0 \left\{\frac{1 + [(\gamma - 1)/2]}{1 + [(\gamma - 1)/2]M_0^2}\right\}^{(\gamma+1)/2(\gamma-1)} \tag{13}$$

where

M_0 = constant
P_{T0} = constant
A_0/A_4 = constant

Increasing the fuel-air ratio increases T_{T_4}. This causes the ratio of (T_{T_8}/T_{T_4}) to decrease. Therefore, the ratio (P_{T_4}/P_{T_8}) would have to increase to hold the right side of the equation constant. The shock would move forward in the diffuser decreasing the total pressure recovery P_{T_4}. Therefore, increasing the fuel-air ratio tends to move the shock forward in the expanding portion of the diffuser.

The effect of the ambient temperature of a shock location could be studied if all other variables were held constant as above. Hold fuel-air ratio, geometry, and M_0 constant. Decreasing the altitude below the tropopause would increase the ratio of (T_{T_8}/T_{T_4}). The ratio of (P_{T_4}/P_{T_0}) must decrease in order to hold the right side of the equation constant. To accomplish this, the shock would move downstream in the expanding portion of the diffuser, resulting in a lower total pressure recovery P_{T_4}. Therefore, decreasing the altitude below the tropopause (and, therefore, the ambient temperature) causes the shock to move farther downstream in the expanding portion of the diffuser.

Summarizing then, it would appear that the correct design for the shock ignition engine would utilize the exit nozzle throat as a throttle. The mass flow would be balanced between this exit throat and the inlet diffuser throat. The variables would have to be selected for some unique solution. The first to be selected would be a flight Mach Number. After this, some desired fuel and fuel-air mixture would be determined. The next step would be to design a diffuser to give the desired pressure recovery and yet allow room near the throat of the inlet diffuser for the fuel nozzles. Mixing should result in a fairly homogeneous mixture upstream of the normal shock. The exit nozzle area would be selected to give the desired shock location when considered with the flight Mach Number and temperature in the combustion zone. The basic idea would be to select the area and total temperature required to locate the normal shock in the downstream portion of the inlet diffuser. This shock wave could be somewhat overintense such that its control and location would be a function of the effective back pressure. The shock wave serving as an ignition source could be defined as a shock ignitor. Its Mach Number would not be dependent on heat release as is the case in a detonation wave.

There are many advantages to such an engine. The ratio of combustion chamber area to inlet capture area for the proposed engine would be less than for similar ram-jet engines. At supersonic flight Mach Numbers below 3.2, this would result in a ratio of combustion area to capture area less than 1, instead of greater than 1 as is the case for the present ram-jet. Therefore the engine drag would be less. In addition, there would be a weightsaving due to the smaller diameter combustion chamber. Then, too, the engine would be lighter because of the elimination of the mechanical flameholders. There would be the added advantage of no pressure loss through the flameholder region.

(*Concluded on page 62*)

New Components for Air-Frame Construction

*Report of Progress**

JOHN F. FAULKNER† and JOHN H. ALDEN‡

Aluminum Company of America

Introduction

Just as aircraft designers are now reducing to practice some of da Vinci's dreams, so Alcoa is developing new products that fulfill some of the air-frame designer's dreams of more efficient structures.

In 1947, the Aircraft Industries Association conducted a survey that brought into focus and gave official standing to a number of proposals for new structural elements that had been under discussion for several years. Using this clear expression of the aircraft industry as a guide, Alcoa concentrated on those items that showed greatest promise. Much of the early work was done without any contracts or orders for material. The aircraft industry was ready, however, to support the various projects by buying the new products as soon as they were offered on an experimental basis. The Air Forces also contributed substantially in the matter of new equipment.

Many important modifications have been made in existing equipment, and new techniques have been developed. Two pieces of large new equipment are installed; others are under construction or on order.

The status of the new products and of related new equipment is outlined below.

Roll-Tapered Sheet and Plate are now being produced, and a new rolling mill and roll-leveler are on order. This equipment will increase the maximum available width, taper, taper ratio, thickness, and flatness of tapered sheet. This mill will also permit greater width and closer tolerances on wide uniform thickness material.

Wide Ribbed Extrusions have been produced commercially in the flattened form. A new extrusion press and stretcher are now being installed, the use of which will enable improvements in size, minimum thickness, flatness, and stress relief of ribbed extrusions and other shapes.

Large Forgings are being produced on a new large hydraulic press recently installed by Alcoa. Forgings of increased size and weight are available from this machine. Additional new presses having up to 50,000 tons capacity are planned for the near future; now is the time to start designing parts for early production on these presses.

Rolled Shape and Forging Stock production is now improved through the use of a new forging press installed early this year.

Ribbed Sheet has been produced in narrow widths. Present techniques are more encouraging than any tried previously for producing wider widths.

Improvements in quality have been effected by Alcoa's rapidly advancing techniques in detecting and correcting imperfections during ingot casting, and through careful inspection with supersonic reflectoscope, of all high-strength alloy ingots and billets, where size permits. Large equipment enables beneficial increases in working, but high-quality ingot is fundamental and maximum soundness cannot be achieved in large products without it.

In the case of all new products, it must be emphasized that only a continuing demand by industry can justify uninterrupted effort by the aluminum producer. Although the industry cannot be expected to make immediate use of every idea that is advanced, it is only reasonable that the aircraft producers share in product developments by purchasing enough material during the pilot production stages to permit a fair appraisal by both parties.

Roll-Tapered Sheet and Plate

Alcoa began the development of roll-tapered sheet in this country about 6 years ago and was rewarded by initial sales in 1948. Since that time nearly 4,000,000 lbs. of roll-tapered sheet and plate have been shipped to aircraft customers in the United States and Canada. Material rolled to date has ranged in thickness from about $^1/_{32}$ in. to nearly $^3/_4$ in., in widths up to 67 in. and lengths up to 25 ft.

Tapered sheet has so far been used for wing and tail skins and for spar webs. Cantilever loading is characteristic of these applications; other uses involving similar loading are anticipated because of the natural suitability of a taper for this type of loading.

Roll-tapered material is of uniform thickness across the width at any point and varies in thickness at a uniform rate throughout its length, as shown in the diagram of Fig. 1. Its taper is achieved by raising or lowering the upper rolls vertically while the sheet is passing through. Fig. 2 shows a view of some tapered

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* The authors are grateful for the substantial contribution of Kirby F. Thornton in conduct of new product developments and preparation of this report.

† Development Engineer.

‡ Chief Metallurgist, Fabricating Division.

sheets for a production jet fighter. This material is more realistic in its proportions, of course, than that shown in the diagram; its dimensions are 0.130–0.047 by 44 by 157 in.

It is evident that the use of roll-tapered sheet is limited to those applications in which it is not mandatory to have integral reinforcement. Such reinforcement can be obtained in ribbed extrusions and "sculptured" plates. More will be said about these later.

In general, tapered sheet production is primarily limited by flattening problems. It is usually possible to roll material of any size and taper that can be satisfactorily flattened.

There are five main advantages in the use of roll-tapered sheet as opposed to the machined product:

(1) Capacity is greater for producing the rolled product in most cases.

(2) Roll-tapered sheet is available with an alclad coating on both sides. This cladding varies in thickness at a constant ratio to the sheet thickness throughout the length.

(3) The rolled product is flatter than its machined counterpart in cases of material too large to stretch.

(4) The surface of roll-tapered sheet normally requires no mechanical finishing.

(5) The waste of machine chips and extra shipping weight is avoided.

The lower portion of Fig. 3 illustrates the weight-saving, as a function of taper ratio, achieved by substituting a tapered sheet for a uniform thickness sheet of equal width and length; the thick end of the tapered sheet is the same gage as the uniform thickness sheet it replaces. Referring again to Fig. 1, it can be seen that the weight saved in such a substitution would be in the form of a "wedge" of metal. The calculation of weight saved is based on the ratio of metal in this wedge to that in the original parallelepiped. This ratio, in terms of thickness, is

$$\text{weight saved} = (1/2)(t_2 - t_1)/t_2$$

When expressed as percentage, in terms of taper ratio (TR), the equation becomes:

$$\text{weight saved, per cent} = 100\,[(TR - 1)/(2TR)]$$

The magnitude of saving would be greater or less if the tapered sheet replaced more or less than one panel.

Present Alcoa equipment limits dimensions to a taper ratio of about 3. New equipment now on order will permit an increase in ratio to about $4^1/_2$.

A significant fact shown by the lower curve in Fig. 3 is the decrease in the rate at which weightsaving is achieved as the taper ratio increases. This diminishing return is aggravated by the difficulty of flattening, which is expensive in dollars, man-hours, equipment time, and scrapped metal.

The upper part of Fig. 3 illustrates the strong influence of sheet width on the flattening problem. It is inordinately harder to flatten wide sheet than narrow sheet. One solution to this problem is to purchase

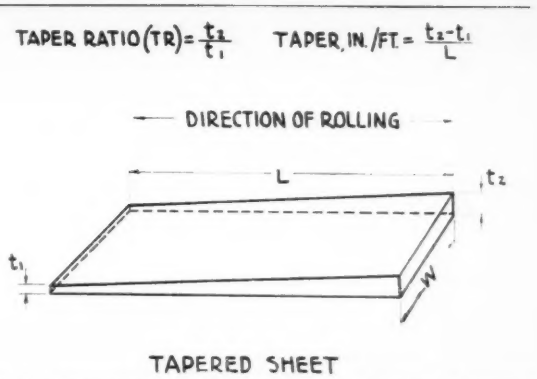

FIG. 1. Schematic drawing, exaggerated, of a piece of tapered sheet.

FIG. 2. Stack of tapered sheet. Each sheet is 0.130–0.047 in. by 44 in. wide by 157 in. long.

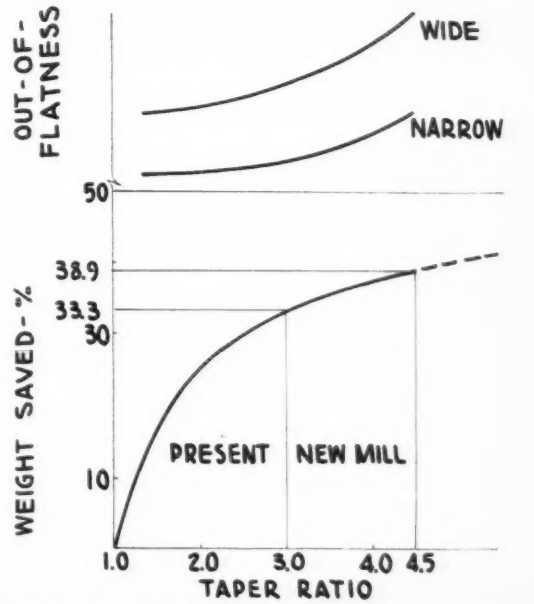

FIG. 3. (*Lower*) Assumes substitution of tapered sheet for equal size sheet of uniform thickness same as thick end of tapered sheet. (*Upper*) Curves are qualitative.

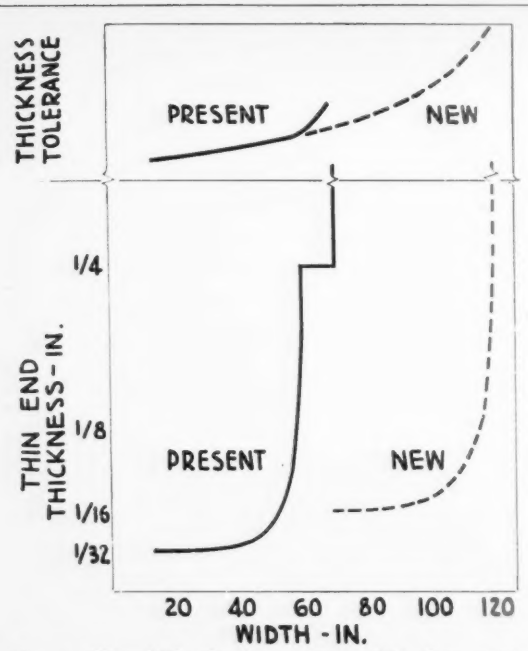

FIG. 4. (*Lower*) Plot showing maximum width of tapered sheet which can be produced on present and future rolling mills for a given thin-end thickness of sheet. (*Upper*) Qualitative plot of thickness tolerances for tapered sheet on present and future mills.

wide sheet in the unheat-treated condition and to use a stretch-forming operation immediately after heat-treating to remove out-of-flatness while contouring the sheet.

Thickness is also a factor in flattening, and it is especially noticeable in the case of tapered sheet. There is much less difficulty in flattening material above about 0.100 in. than there is with thinner sheet.

The flattening of tapered sheet is done in the freshly heat-treated condition within the shortest possible time after quenching to take advantage of the superior formability available at this time. The close timing and rapid handling necessary to accomplish this technique make the flattening operation expensive, but it is the only way that has been found to achieve satisfactory flatness.

Fig. 4 depicts the limiting effect of thickness on width for the present and new mills. The maximum width of 60 in. applying to present sheet under about 0.250 in. thick is controlled by close tolerance (cold) rolling equipment. Larger (hot) mills having coarser gage control are used for widths from 60 to 72 in. The new mill is designed to provide the fine control and power necessary to cold-roll wide sheet and plate, thus achieving closer tolerances. Note the upper curve on Fig. 4.

Means for controlling taper will be provided in the power system for this new mill, which will allow more flexibility than the modified controls on present equipment. This mill is to be installed at Alcoa's Davenport, Iowa, Works. It will be capable of producing sheet and plate in thicknesses from $^1/_{16}$ to $1^1/_2$ in., and up to 120 in. wide for all but the thinner gages.

TABLE 1

Dimension	Present	Future
Length	38 ft.	38 ft.
Width, sheet	60 in.	120 in.
Width, plate	72 in.	120 in.
Taper rate	0.025 in./ft.	0.050 in./ft.
Taper ratio	3	4.5
Thickness, maximum	0.750 in.	1.5 in.
Thickness, minimum	0.032 in.	0.032 in.
Thickness tolerance	Commercial* +0.001	Commercial*

* Standard commercial tolerances for gage and width of uniform thickness sheet corresponding to any given location on tapered sheet.

The presently available and anticipated future maximums in dimensions of roll-tapered sheet and plate are detailed in Table 1.

Many combinations of the extremes given in this table are, of course, impossible. Any combination involving more than one maximum is usually marginal and subject to experimental production restrictions. In cases involving moderate dimensions, there is usually no production problem. Although tapered sheet is a custom-made product, delivery can be obtained in almost the same time required for a mill shipment of uniform thickness sheet. Some extra time must be allowed for a presale inquiry before the order is actually accepted.

The roll-leveling machine included in the new installation for tapered sheet production will have controls to accommodate tapers up to the mill maximum of 0.050 in. per ft.; its capacity is chosen so as to complement present equipment.

All the roll-tapered sheet produced so far has been of alloy 75S. Other alloys are available if required.

There has been a good response to tapered sheet developments. It is felt that there are many places where it might yet be used to advantage if designers would carefully consider its benefits in all the possible applications, but its acceptance to date has been reassuringly widespread in the industry.

The new mill will also increase the width of uniform thickness material which can be rolled in thick sheet and thin plate ranges. The present limits for these two thickness classes are 60 and 90 in., respectively; the new limit will be 120 in. in both cases. The thickness tolerances of material wider than the present commerical limits are usually subject to some increase with present equipment. It is anticipated that the new mill will make unnecessary the additional tolerance on wide sheet such as shown in Fig. 5.

The availability of wide sheet and plate having close thickness tolerances gives obvious advantages both for direct use and for "blanks" to be machined. The latter type of "sculptured" component is capable of high structural efficiency because of the integral reinforcing that can be achieved.

WIDE RIBBED EXTRUSIONS

This discussion deals only with shapes of sufficient width to require extruding in a "compressed" width configuration.

Alcoa's first production of this type section was nearly 12 years ago. At that time a shape was extruded for Grumman Aircraft Engineering Corporation, measuring about $17^1/_2$ in. wide and $^5/_{32}$ in. thick and having three ribs on one side. The urgency of World War II production overtook the project, however, and nothing more was done until after the war.

In 1946, Alcoa began another project on a similar shape for Boeing Airplane Company. This section was about $19^1/_4$ in. wide and $^3/_{16}$ in. thick, with 4 Tee stiffeners. Several charges of this shape were extruded. Then started the long and discouraging task of learning to flatten such shapes from their as-extruded contours. This particular section was extruded in a horseshoe-like cross section. All efforts to flatten it were unsuccessful, so it was decided that a Vee-shape section should be made to avoid the necessity of flattening more than one curved region. Fig. 6 shows the earlier and later versions of this shape. Flattening of the Vee was successful.

A much wider shape was produced in 1950; it was extruded as shown in Fig. 7, using a mandrel and a hollow ingot. Its width after flattening was about 36 in. and thickness $^3/_{16}$ in., with five Tee stiffeners each 2 in. high by 0.140-in. stem thickness. Flattening of this

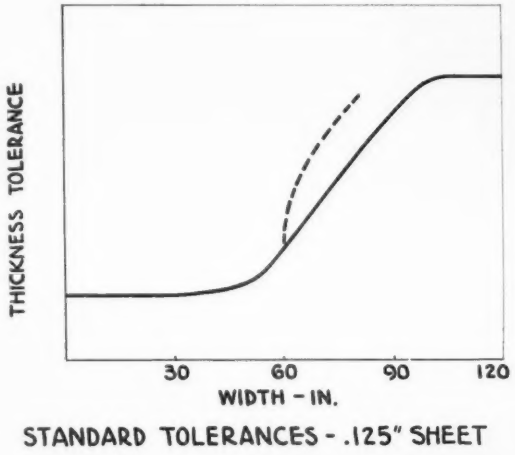

FIG. 5. Dotted line shows greater tolerances required for wide strong alloy sheet on present equipment.

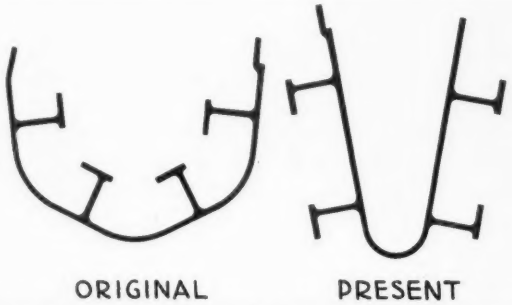

FIG. 6. Cross-sectional views of the original and the present commercial version of a wide ribbed extrusion in the as-extruded form. Developed width is $19^1/_4$ in.; thickness is $^3/_{16}$ in.

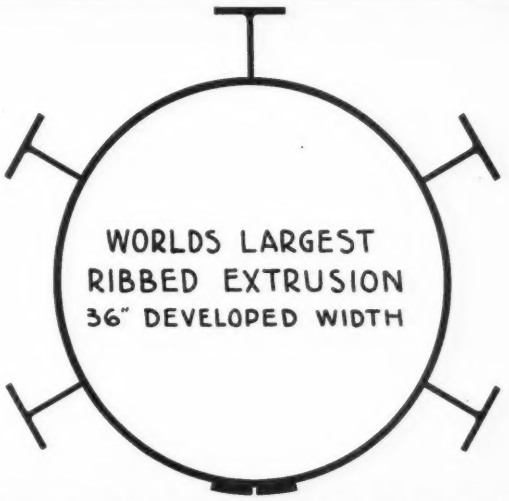

FIG. 7. Large ribbed extrusion extruded as a hollow section. Thickness is $^3/_{16}$ in., except stiffener stems that are 0.140 in.

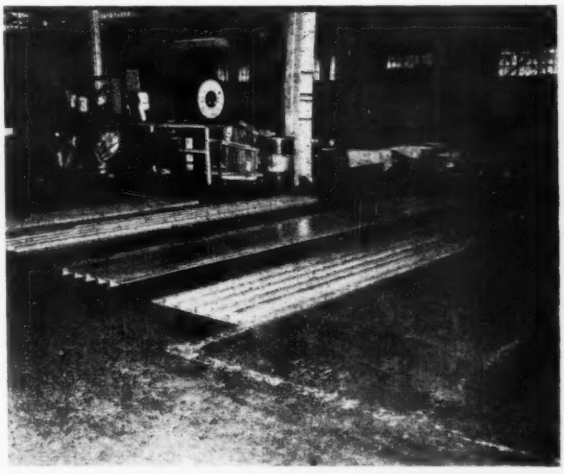

FIG. 8. Four pieces of 36-in. wide ribbed extrusion after flattening.

FIG. 9. Production lot of a wide ribbed extrusion after flattening. An as-extruded section of this shape is shown at the right front corner of the front stack.

TABLE 2
Tentative Manufacturing Limits for Normal Extrusions

Circumscribing Circle Diameter, In.	Minimum Thickness—Solid Shapes—In.			
	3S-63S	61S-62S	14S	24S-75S
Under 13	0.093	0.109	0.125	0.156
13 to (not incl.) 16	0.109	0.125	0.156	0.187
16 to (not incl.) 19	0.125	0.140	0.171	0.250
19 to (not incl.) 23	0.140	0.156	0.187	0.375

These thickness limits are applicable to the average solid shape. Greater thickness may be necessary for some shapes; less thickness may be possible for others.

shape was relatively successful but not practicable commercially.

The Vee-shaped section is best adapted to commercial production, and a flatness tolerance of 0.008 in. per in. of width is now considered standard.

The flattening of ribbed extrusions from the as-extruded Vee to the final flat shape is done in the annealed temper. After flattening, they are heat-treated, quenched, and stretched conventionally.

Fig. 8 shows some flattened pieces of the 36-in. wide extrusion mentioned above. A later shape, one of the first production runs on wide ribbed extrusions, is shown in Fig. 9. The as-extruded Vee of this section is seen at the right front corner of the front stack.

The limitations on maximum widths and minimum thicknesses of various alloys producible on present and future equipment are shown in Fig. 10. The new equipment that effects this improvement is a 13,200-ton extrusion press now being moved to this country from Germany for installation at Alcoa's Lafayette, Ind., Works.

This new press has other advantages, of course, besides improving the width and thickness of wide

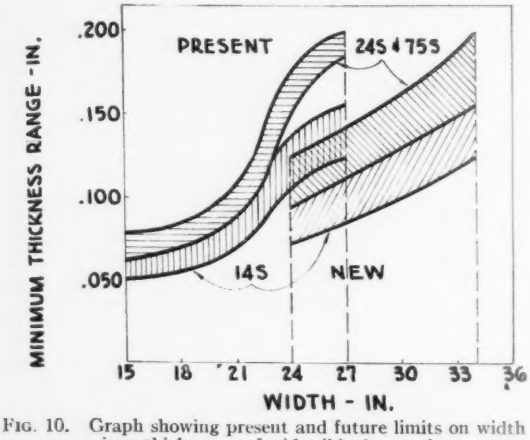

FIG. 10. Graph showing present and future limits on width for given thicknesses of wide ribbed extrusions.

FIG. 11. One-piece extruded spar after machining.

ribbed extrusions. Table 2 gives an idea of its limitations on circle size and thickness of solid shapes. Although these limits are tentative, sufficient experience has been gained on present equipment to assure good agreement between estimated and actual capacity.

In addition to the above improvement, the new press will be capable of producing extrusions weighing 2,300 lbs. as compared to the present maximum of about 600 lbs. This will permit wider usage of one-piece spars and also eliminate splices in spar caps used in conventional built-up spars. Other assemblies may be replaced by fewer, larger pieces as shown in Fig. 11.

The new stretcher, which is to be installed as an auxiliary to the extrusion press, is of great importance because of the strong influence that stretching exerts in reducing warpage during machining. Fig. 12 illustrates graphically the effect of stretching on a piece of material having the same strength throughout the cross section and containing internal stresses of about 10,000 lbs. per sq. in. in tension at one location and the same magnitude in compression in another part of the same cross section. The resulting stress-strain curves are identical except for horizontal displacement. Stretching into the plastic range results in a reduction of the original stresses to values of only a few hundred pounds per square inch, and machining distortion is practically eliminated.

The desirable condition of uniform strength is normally present in 75S, but not in 14S and 24S, alloy shapes. In these latter alloys, the outer portions tend to recrystallize upon heat-treatment because of extensive working in the extrusion process. Recrystallized material is generally lower in longitudinal strength than the unrecrystallized metal. Stretching of such shapes obviously will leave a condition of compressive strain in the weaker material and tensile strain in the stronger unrecrystallized portions.

If the shape is asymmetrical, as is often the case, stretching will cause it to bow toward the region with the least recrystallized material. Commercial practice normally requires straightness in preference to low internal strain, so such bow is usually removed by bending. This straightening creates a new pattern of residual stresses so that machining warpage may still be a problem.

A special temper in one alloy—namely, 14S-T64—provides a real improvement over 14S-T6 and 24S-T4 in low residual stress and is susceptible to good strain relief by stretching. Lower mechanical properties

accompany recrystallization of thicker sections so that there is some disadvantage in the use of 14S-T64 over $^1/_2$ in. thick, but the cases in which the thickness is less than $^1/_2$ in. or the warpage problem is acute can be benefited by the use of this temper.

Distortion during machining and straightening afterwards are especially difficult to cope with in the case of large heavy extrusions. Many extrusions produced on present presses are too large for existing stretchers, and, of course, the new press will increase the number of large sections produced. On present equipment it is only possible to stretch extrusions having an area less than about 18 sq. in., so all larger sections will be improved by the availability of the new stretcher that will handle up to fully 60 sq.in.

Fig. 13 shows the preparations required for installation of the new stretcher. The capacity of this unit is 3,000,000 lbs., which means that an enormous resisting structure must be built not only to accommodate the static load of stretching but, more important, to withstand the tremendous impact load when an extrusion breaks during stretching.

Large Forgings

During the years since World War II, a trend that started early in the war has built up more and more urgency. Complicated assemblies are being eliminated in favor of large single parts having greater structural efficiency, saving weight, space, and usually expense. Large aluminum forgings have been used for a few of these applications, but there have been many cases in which forging capacity was not great enough to accommodate the dimensions or the details required for the design. There has been only one large press available, so it has been necessary to screen tentative designs and eliminate many, which were quite desirable from the structural standpoint, because of limited capacity.

With the recent addition of a large forging press to Alcoa's facilities, some of the burden has been removed from the original large press. This makes it possible to continue at least partial production in the event of breakdown on one press and greatly increases the capacity under normal conditions. Both of these presses are Government-owned, operated by private enterprise. The earlier press has a capacity of 18,000 tons and is operated by Wyman-Gordon Company at Worcester, Mass. The press operated by Alcoa has a capacity of 15,000 tons and is located at Cleveland, Ohio. Fig. 14 shows a view of the later press and gives some idea of its size.

The die table on this press will accommodate a forging of about 5 by 18 ft., although there are few parts that could be forged with a plan form of this great

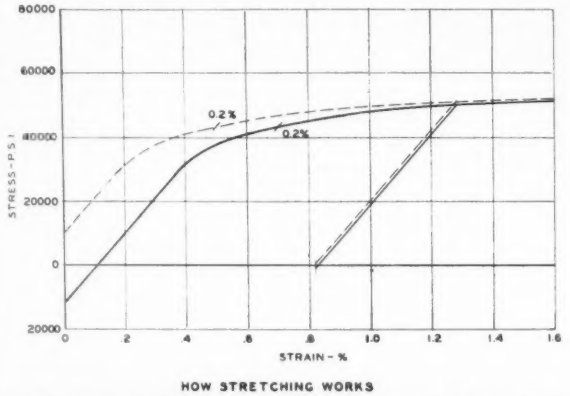

Fig. 12. Plot of theoretical stress-strain curves in homogeneous cross section containing residual stresses as shown. Stress relief is achieved by stretching.

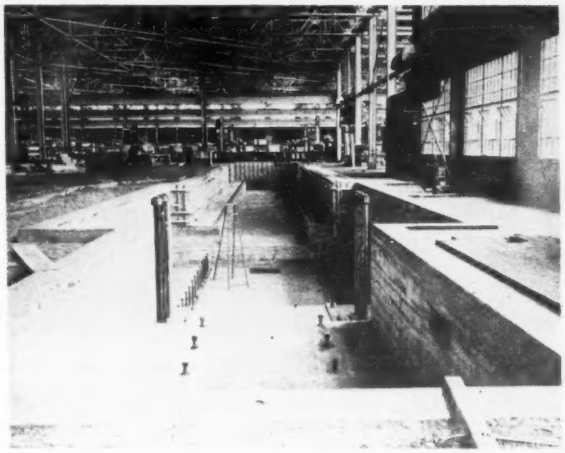

Fig. 13. Excavation and the surface of the foundation structure required for new 3,000,000-lb. shape stretcher being installed at Alcoa's Lafayette, Ind., Works.

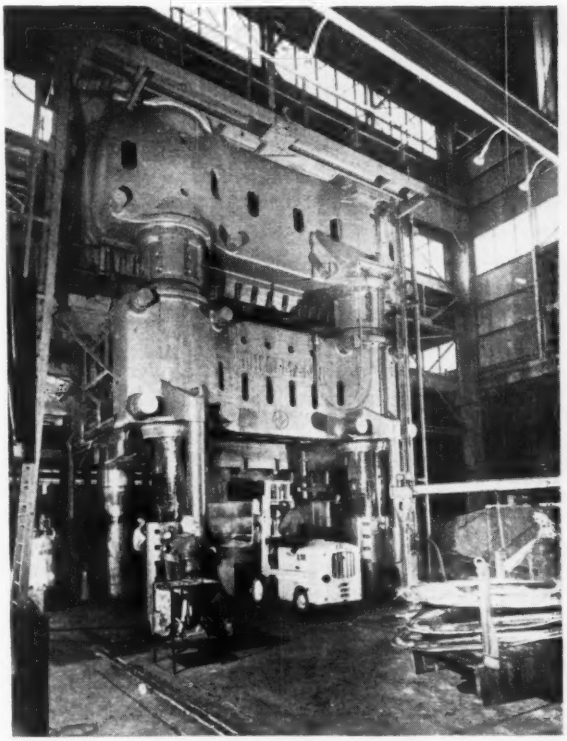

Fig. 14. New 15,000-ton hydraulic forging press in Alcoa's Cleveland, Ohio, Works.

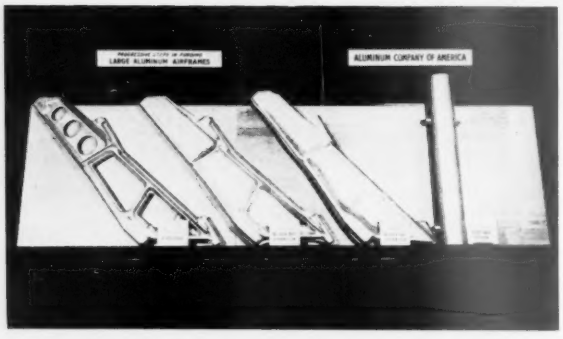

FIG. 15. Large die forging made on 15,000-ton press. This part required little machining and is well designed from forging standpoint. *Left to right:* Finished forging; two intermediate blocking operations; forging stock.

area. It is necessary to exert forces on the order of 50,000 to 75,000 lbs. per sq.in. in making forgings, so it is apparent that an area of 4 to 5 sq.ft. would require about full capacity of the press.

Many design details increase the pressure requirements; such details are discussed in an article entitled "Aluminum Die Forging Design" by A. E. Favre and A. J. Orazem, published in *Product Engineering* magazine in three parts, August and September, 1950, and January, 1951. In addition, the above article covers some economic factors, tolerances, forging defects, etc.

The largest die forging produced by Alcoa to date is the truss-type member shown in Fig. 15. This part is a good combination of forging and structural design. It has no details that would make it marginal in the forging operation, and only about 15 per cent of the as-forged weight is removed by machining before final use.

In designing a forging it is usually necessary to have accurate mechanical properties for many locations in the part, in addition to the "longitudinal" properties quoted in ANC-5. Upon request, Alcoa will consult with the designer and advise him of such properties during the design stages. Tests to substantiate such values will be made by surveying one or more actual parts after forging if desired. It has long been the accepted practice for the designer and the forging engineer to cooperate extensively in working out the details of forgings to the best advantage of both. With the advent of new large equipment and larger forgings, this practice becomes more important if the best utilization is to be made of the equipment.

Plans are now under way for the construction of a series of forging presses having capacities up to 50,000 tons. Such presses will be capable of producing parts many times larger than heretofore available.

One of the important considerations in their use will be whether designs should be aimed at the goal of total refinement in an effort to eliminate the maximum amount of machining or whether to increase the size of forgings in an effort to improve integration of components. The former approach seriously limits the total size and involves tooling difficulties in return for its obvious advantage of requiring minimum finishing by the user. The latter case can be expensive from the machining standpoint, although its ultimate possible structural efficiency appears to be greater.

In connection with ultralarge die forgings, there is always the consideration of prototype parts that must be cut from hand-forged blocks. The size of a given die forging may thus be limited by the size of hand forging available. One solution to this problem is the use of semiforged parts that can be made to simulate the "envelope" of the part more closely than a conventional block or biscuit. The time, expense, and extent of working on such a shape are intermediate between those of die and hand forgings.

If this expedient does not suffice, it may be necessary either to reduce the size of the die forging or to eliminate extremities that cause the envelope dimensions to be excessive.

One of the steps in forging production that promises to be an increasingly serious problem is die-sinking. Equipment size, feeds, and speeds must be increased, and more machines will probably have to be obtained if die-sinking time is to be held to a reasonable percentage of the total production time.

Large plan-dimensions tend to complicate the tolerance problem because of tolerances on the die model, the die-sinking, and variations in the temperature of the die and of the stock. The machining allowances required can become burdensome and in some cases might even justify a fundamental change in the design.

A thorough consideration of the above and other related problems leads to the conclusion that forging designs to be produced on the future large presses should be initiated as soon as possible. Based on the present state of development, there will be 2 to 3 years required from the initial proposal stage to the delivery of a typical forging produced on the new presses, and the present rough estimates of when the large presses will be in actual production exceed this span only slightly, if any.

ROLLED SHAPES AND FORGING STOCK

For several years, Alcoa has been producing large rolled shapes for use as spar caps by one of the major aircraft manufacturers. The reason these parts have been rolled rather than extruded is that the weight per piece can be considerably greater in the rolled shape, its limit being roughly 2,000 lbs., compared with about 600 lbs. for the extrusion maximum.

Although the new extrusion press will be able to produce parts up to about 2,300 lbs., it is also possible that the rolled-shape limit will be increased substantially in the future, so it may again have a weight advantage. It should be pointed out that such an advantage must be substantial to enable a rolled shape to compete with an extrusion, because the rolled section requires greater tolerances and much larger radii and fillets. Even so, developments seem to presage rolled shapes big enough to compete with the largest extrusions.

Forging stock, which is mainly rolled rounds and squares, is the biggest item of rolled stock ultimately used by the aircraft industry. This material is used in both hand and die forgings.

Recently, it has been established that large forging stock can be improved by doing the first work on the ingots by pressing rather than rolling. In order to facilitate this procedure, a new 3,000-ton forging press has been installed at Alcoa's Massena, N. Y., Works. Fabricating and metallurgical studies have made this step expedient, and it is anticipated that the improved flexibility possible with combined equipment will benefit both rolled and forged products, especially in the larger sizes of high-strength alloys.

Ribbed Sheets

Efforts to make ribbed sheet have emphasized the relative difficulty of working high-strength alloys as compared to the softer "common" alloys. Extreme distortion of the sheet and roll pressures high enough to coin even the roll surface are examples of such difficulties.

This product has an obvious advantage for many air-frame uses because of its high stiffness-to-weight ratio. The attendant interest in it has prompted considerable development work. Even though 3S alloy ribbed sheet was produced commercially as long as 15 years ago, no success was achieved in rolling high-strength alloys in this form until recently.

A new technique has been promising in recent experiments on narrow widths. Samples were made in 75S in which the web was rolled down to about 0.026 in. The ribs were $^{5}/_{32}$ in. high spaced on 1-in. centers. Such material is not yet available, but it is anticipated that future developments will enable its production in a usable width sometime in the near future.

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Cockpit Design and Safety

WILLIAM I. STIEGLITZ*
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Introduction

Statistical analyses of accidents indicate pilot error to be the commonest cause; however, a careful study of such statistics reveals a wide variety of types of error. Some of these are basic errors in judgment or in flying technique, but the great majority involves mistakes in cockpit procedure or in the use of controls, or misinterpretation of instrument readings or warning signals. In such cases, it is true that immediately preceding the accident the pilot committed an error, but frequently careful analysis reveals that an earlier error had been made in design, making the pilot's error highly probable under some given set of conditions. It is the purpose of this paper to analyze such accident potential and to indicate means by which it can be reduced.

The Man-Machine Relationship

The increased size, speed, altitude, and range of the modern airplane have resulted in a continually increasing complexity of instrumentation and cockpit controls. Only one element in the cockpit remains unchanged and unchangeable—the pilot.

The man who is flying the airplane of today, and who will be flying the airplane of tomorrow, is fundamentally the same as the man who, a few years ago, was flying a 100-m.p.h. stick and throttle airplane. His attitudes have changed; he is more willing to face complex situations involved in operating mechanical devices. He is, however, subject to the same basic limitations. His mental and physical reactions are fundamentally the same, and his reaction time is unchanged.

The result of this combination of the unchanging man and the increasingly complex machine has been that at times the demands placed upon the man have exceeded basic human limitations, and accidents have occurred. Many such accidents can be prevented. This can be achieved only by design that gives full consideration to both the abilities and the limitations of the pilot.

Environmental conditions and operating requirements are considered throughout the design of an airplane, not only as affects the aerodynamic characteristics and structural loads but also with regard to the installation of equipment. In many cases, equipment is not available which will operate under the environmental conditions of the airplane; in such cases, the engineer modifies the local environment to meet the requirements of the equipment. This same approach has already been applied to some extent to the pilot's physical environment; cabin air conditioning and pressurization, and proper seating, are a few examples. Physical limitations are only one part of the human factor: it is necessary that similar consideration be given to the pilot's psychological patterns.

Knowledge of these patterns, of the basic nature of man, is therefore essential. Fortunately there is much pertinent information available as a result of research in the field of Human Engineering, which has been defined by Beals as "the application of psychology, physiology, medicine, anthropology, and engineering to the Man-Machine relationship—or in this instance the Aviator-Airplane combination, primarily."[1]

We have not in the past made full use of the data derived from research in this field. Many costly errors could have been avoided had we done so. We must, in future design, make full use of the data already available and of that which will result from continuing research.

The Problem

Any engineering problem must be defined before it can be solved. In this case, definition of the problem requires an examination of the ways in which the increasing complexity of the airplane has affected the unchanged pilot. Basically, these can be put under three main headings.

First, the airplane has greater speed, range, and endurance and flies at higher altitudes. Further, higher wing loading has resulted in larger maneuvering radii. As a result of these factors the pilot has less time to make decisions, and must be more accurate because of the decreased margin for error; if a mistake is made, there is little time to correct it. In addition, high-altitude, high-speed flight is resulting in new navigational problems, which are being further complicated by the advent of in-flight refueling, with its associated requirement for pinpoint rendezvous.

Second, the improved performance described above and more complex functional systems have resulted in a greatly increased amount of instrumentation, including not only flight and engine instruments but warning signals and electronic equipment. Thus the pilot is being provided with more information, from more sources. All of this information must be recognized, analyzed, and correlated.

Presented at the Design Session, Annual Summer Meeting, I.A.S., Los Angeles, July 16–18, 1952.

* Design Safety Engineer.

Third, the number of controls in the cockpit has increased correspondingly. Frequently a complex sequence of control manipulation is necessary. Test data have shown that human reaction time definitely increases with the number of stimuli and the complexity of the discrimination to be made.[2] Therefore both the increased amount of instrumentation and the greater number of controls tend to increase the time required for the pilot to assess a situation and take the necessary action. Thus, the combined result has been that greater precision is demanded of the pilot, less time is available to him in which to act, and yet he requires more time than previously.

Du Bois has pointed out that "when a pilot has been properly trained in flight, the instruments become part of a new sensory external nervous system, and the controls merely an extension of his motor system."[3] This appears to the writer to be more a statement of the goal to which we must work than of the situation as it exists today.

Instrument Displays

As applied to the problem of instrumentation, achieving this goal requires that information be presented to the pilot in a readily understandable form which does not require conscious interpretation. The inadequacy of present instrument display is well demonstrated by the fact that it requires approximately the same length of time to train pilot personnel in instrument flying as it does to train nonflight personnel.[4]

This demonstrates that proficiency in visual flight is of little value in instrument flight, in that the latter requires learning an entirely new system. Obviously, if the instrument display provided cues more like those of visual flight, not only would training be facilitated, but transition from visual to instrument flight conditions would be considerably simpler, and instrument flight would be less fatiguing than it now is.

The ultimate solution to such problems must come not only from design and improvement of individual instruments but from the development of an integrated instrumentation system. There is no need here to dwell at length on this approach, since it has been presented by Beals.[4] Certainly, as Beals has pointed out, this is a problem that will require the combined efforts of psychologists, engineers, pilots, and flight surgeons and cannot be left solely to instrument specialists.

Development of such a system will require time. Meanwhile, there are other phases of the instrumentation problem toward the solution of which immediate steps can be taken. One is the elimination of the indiscriminate mixing of fly-to and fly-from indications, which require the pilot repeatedly to shift his frame of reference from the airplane to the ground and back again. Another is the improvement of the displays of those present types of instruments already proved to be unsatisfactory.

An example of this is the multiple-pointer instrument, such as the current standard altimeter. A survey made by Fitts and Jones of actual cases of misreading of instruments showed that 40 of a total of 270 incidents, or approximately 12 per cent, involved multiple-pointer instruments.[5] Subsequent tests, using Air Force pilots as subjects, revealed that the standard altimeter was misread by 1,000 ft. or more in 11.7 per cent of the cases and required an average interpretation time of 7.1 sec. Out of twelve altimeter readings presented to each of the pilots, one setting was misread by 68, and another by 51, of the 97 subjects.[6,7]

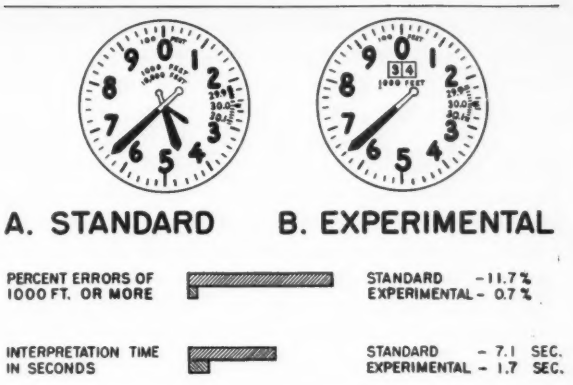

Fig. 1. Comparative speed and accuracy in reading a standard and an experimental altimeter.[6]

In contrast, an experimental-type instrument, with a single pointer and the thousands of feet shown on a Veeder-type counter, was misread in only 0.7 per cent of the cases, with a mean interpretation time of 1.7 sec. A comparison of the standard and experimental instruments is shown in Fig. 1.

Instrument Arrangement

Another aspect of the instrumentation problem is instrument arrangement. At long last, definite steps have been taken by the Armed Services and by the aviation industry to develop a standard grouping of the basic flight instruments. For several years, many air lines, the Air Force, and the Navy have had individual standard arrangements, but few, if any, of these standards have been the same. The use of airline equipment by the military in time of emergency and the increasing interchange of equipment among air lines emphasize the importance of the development of a single common standard.

The very fact that so many different standards have been in use, with comparable safety, would indicate that as long as a well-planned arrangement is used the exact grouping is of less importance than the existence of a standard arrangement, so that the same instrument is always in the same location. It is desirable that the arrangement be such that the instruments most commonly used are most easily seen, and the most frequent eye movements are as short as possible.

A series of tests being conducted by the Air Force on pilot eye fixations during instrument flight[8–13] provides a sound basis for arriving at such a grouping.

Most of these tests have been conducted using the current standard Air Force panel, but a comparison during ILS approach was made with an experimental arrangement. As might be expected, the change in arrangement had little influence on the frequency with which the pilot referred to the various instruments, or the length of the individual eye fixations: it did have a major influence on the sequence of instrument readings. Also, as would be expected, the tests indicate that what might be the optimum arrangement for one flight condition is not necessarily the optimum for others, since both the relative importance of instruments and the sequence of eye movements change.

Within the past few months, an industry group has arrived at a recommended standard instrument panel for commercial transport aircraft. Also, agreement has been reached between the Air Force and the Navy on a common standard. Certain differences exist between the arrangement adopted by the Armed Services and that recommended by the industry group. It is to be hoped that such differences will be resolved in the near future.

Controls—and Accidents

The other major phase of the cockpit design problem concerns controls. Referring again to the Human Engineering concept, the controls should serve as an extension of the pilot's motor system. This requires that control motion be completely natural for the pilot so that his only decision need be what effect he wishes to produce, without the need for conscious determination of which control to move, where it is, and in what direction to move it. Selection of the proper control is a matter of pilot training: control location, identification, and direction of motion are a matter of design. To what extent past design has been inadequate can best be seen by reference to the record.

In an analysis of 460 actual pilot errors in the operation of controls, Fitts and Jones[14] found that the errors were of six basic types. These types and the frequency distribution are shown in Fig. 2. The following description is quoted directly from the Fitts and Jones report:

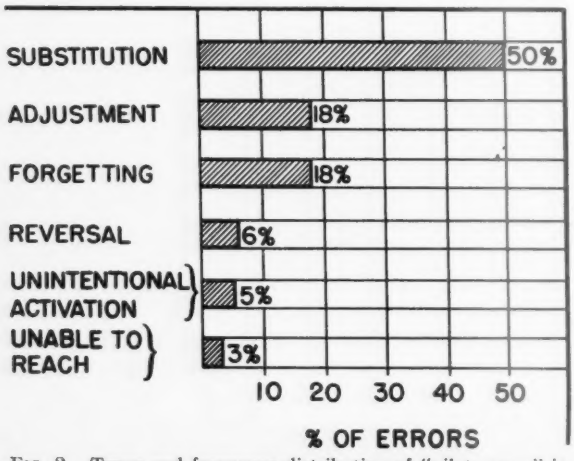

Fig. 2. Types and frequency distribution of "pilot errors" in the use of controls.[14]

"*Substitution errors*, in which the wrong control was operated, constituted exactly 50 per cent of all the error descriptions collected. The most common sub-types of errors under this general category were confusion of throttle quadrant controls (19 per cent), confusion of flap and wheel controls (16 per cent), and using the wrong engine control or feathering button (8 per cent).

"*Adjustment errors* and *Forgetting errors* each accounted for an additional 18 per cent of all errors.

"Three additional categories, *Reversal errors*, *Unintentional Activation*, and *Unable to Reach* accounted for the remaining 14 per cent of error reports."

The authors of the report point out that the frequencies with which the different types of error were described in the survey do not represent the precise frequency with which each type of error occurs. Further, this survey was conducted among military pilots, and a further variation in frequency distribution might be found if a similar survey were made of air-line pilots. Nevertheless, it appears that the types of errors would be the same and that the general relative frequency would not vary much.

In order to illustrate the sources of such errors, examples of various types of errors are cited below. These examples are not limited to those from the Fitts and Jones study.

Substitution Errors

The pilot of a twin-engined aircraft, observing smoke from the left engine, feathered the propeller and shut down the engine. Immediately thereafter, power failed on the right engine and a crash landing resulted. In the investigation, it was found that in shutting down the left engine the pilot had turned off the fuel to the right engine instead of the left. In this airplane, all engine controls except the shut-off valves were installed in front of the pilot, and so arranged that the controls for the left engine were on the pilot's left, and those for the right engine on the pilot's right. The fuel shut-off valves, however, were installed along the left side of the cockpit, and so arranged that as the pilot faced them the fuel shut-off for the right engine was toward the pilot's left.

One of the commonest types of substitution errors has been confusion between flap and landing-gear controls. An example of this occurred following the landing of a transport aircraft at the end of a trans-oceanic flight. As the aircraft was taxiing in, the pilot signaled to the copilot to pull the flaps up. The co-pilot, who was on his first trip in this model airplane after extensive experience in a different model, reached over and pulled up the landing-gear control, which was in the same position as the flap control had been in the airplane with which he was familiar.

The frequency with which this particular error has been a factor in accidents is also shown by Air Force

statistics for the 22 months from January, 1943, to November, 1944. During this time, confusion between flap and landing-gear controls was a cause factor in 457 accidents, of which 184 occurred in fighters, bombers, and transports.[15]

Adjustment Errors

The most frequent types of adjustment errors occurred in the use of fuel selectors, with the switch either being turned to an empty tank or being left in an intermediate position. Failure to obtain desired flap settings and improper trim adjustment are also common types. The effect of such errors is so readily apparent that there seems little need to cite specific examples.

Forgetting Errors

A casual study might incline one to assume that the pilot's forgetting to operate controls would be primarily a matter of pilot training, and not of design. However, frequently such errors are the result of either the pilot's having too many duties to perform at a given time, or of unnecessarily complex procedures. One example occurred in a twin-engined transport in which the pilot in switching fuel tanks fed both engines from a single tank on cross feed, but then failed to turn off the nearly empty tank from which he had been drawing. Air sucked from this tank caused power failure of both engines and a forced landing. Simplification of fuel system controls or automatic fuel sequencing would have rendered such an error impossible.

Inadvertent Activation

As the pilot of a fighter aircraft retracted the landing gear after take-off, total power failure occurred, and the aircraft was landed wheels-up off the end of the runway. It was found that as the pilot retracted the landing gear, the main fuel shut-off, which was actuated by a toggle switch directly below the landing-gear handle, had been flipped into "off" position by the pilot's glove.

Reversal Errors

During landing approach, the pilot of a four-engined aircraft signaled to the flight engineer for full-rich mixture. Immediate power failure occurred on all engines, and the airplane crashed short of the airport. In this particular type, the mixture controls moved forward for idle cutoff, whereas on all other types with which the flight engineer was familiar, the forward position of the control was for full-rich mixture.

Control Location and Coding

The foregoing review of control errors suggests several types of possible corrective action. One would appear to be adequate separation of controls. Tests conducted by Air Materiel Command, and discussed and analyzed by Chapanis,[16] show that human accuracy in reaching for a fixed point is comparatively poor. The smallest mean error was in reaching for a target directly in front of the subject at shoulder level, and in this case the error was approximately 2 in. With the target above or below shoulder level, slightly behind the subject and to the side, the error was approximately 4 in.

Chapanis points out that an average error will only cover 50 per cent of the cases, and that to be sure of covering all possible errors requires a multiplying factor of from three to four. Thus, in order to eliminate the possibility of control error by means of physical separation, spacing of from 6 to 8 in. would be required for those controls directly ahead of the pilot, and double this amount for those on side panels. Such spacing is impossible in an airplane cockpit. Therefore other measures must be taken to eliminate control confusion.

There are two effective and practical means of accomplishing this: shape coding of critical knobs to permit tactual discrimination, and standardization of location of controls. By the latter is meant not rigid dimensional standardization but rather that a given control always be in the same area and that controls be in the same position relative to each other.

In tests using typical throttle quadrant controls, Weitz definitely demonstrated the value of both of these measures. From one group of tests, in which visual cues were present,[17] Weitz concluded that "maintaining position of controls is of primary importance, yet if the position is changed and the shape of the handle remains constant, little loss in performance is encountered. The most efficient procedure is to maintain both position and shape constant."

In other tests, in which visual cues were eliminated,[18] coded knob shapes still provided a definite improvement in performance. Thus, even where spacing is completely inadequate to afford discrimination, fixed relative position is of definite benefit under conditions permitting visual reference. On the other hand, in a darkened cockpit shape coding is essential, and is of benefit at all times.

If coded knob shapes are to be of maximum value, they must be such as to be recognized immediately through the sense of touch alone. Tests conducted by the Air Forces resulted in a group of knob shapes meeting this requirement.[19–21] These, however, were arbitrary shapes, requiring that the pilot memorize which shape applied to which control. Thus while these shapes provide positive tactual discrimination, they furnish no associative cues. Such cues can readily be provided by shaping the knob to correspond to the unit being actuated, as, for example, a miniature wheel for the landing gear control and an airfoil section for the flap control. The Armed Services have adopted standard knob shapes for critical controls on this basis, using the arbitrary shapes resulting from the tests for controls, such as fuel mixture, for which there is no simple associative form.

Definite progress toward standardization of cockpit arrangement has been made. Standard control locations for single-place cockpits were established by the Armed Services a few years ago. Within the last few months, an industry committee and the Munitions

Board Cockpit Layout Panel have come to complete agreement on similar standards for multiplace cockpits for military and commercial aircraft. Such joint agreement on knob shapes is also needed.

One other factor to be considered in control location is related to the pilot's physiological rather than his psychological characteristics. One type of error noted above from the Fitts and Jones survey was labeled "Unable to Reach." Such "pilot errors" can be prevented by design that utilizes anthropometric data. On the basis of reach measurements, King has tabulated the maximum distances at which a large majority of pilots would be able to reach and operate manual controls.[22] Failure to consider such measurements is well illustrated by one multiengined aircraft, in which it was found that many controls were located as much as 15 in. beyond the fingertip reach of 50 per cent of the pilots. In this airplane only the side control panel was within normal reach.

Control Motion

Control motion is just as important as control location and identification in eliminating pilot difficulties. Here the requirement is that control motions be natural and conform to basic habit patterns. The selection of natural motions is largely a matter of common sense. The first rule for naturalness in control motion is that the control move in the same direction and sense as the unit being actuated. For example, if a landing-gear control moves down to extend the landing gear there will be no confusion. If, on the other hand, the control were to move up to put the landing gear down, frequent errors could be expected. Also, were the control to move sideward, complete ambiguity of response could be expected, since there would be nothing to cue the pilot as to proper direction of motion.

In the case of controls for which there is no such direct association, psychological data afford a sound basis for determining what is natural. In designing such controls, the habit patterns of everyday life must be considered and utilized.

A simple example of such a habit pattern is in the use of rotary controls. Everyone uses switches of this type every day; volume controls on radios and gas valves on cooking ranges are typical examples. All these controls are designed so that clockwise rotation produces increased output—that is, the volume control on a radio turns clockwise to increase volume, etc. If this sense of motion is maintained in the cockpit, the carry-over of this habit pattern will assist in prompting correct actuation. On the other hand, if cockpit controls are designed so that clockwise rotation produces decreased performance, a definite conflict with previously established habit patterns will exist. Training will not eliminate this conflict because of the reversion to the previous pattern whenever the pilot is not flying. To design a rotary switch for an airplane so that clockwise rotation reduces output is to invite pilot error. This is particularly true in an emergency, since under conditions of stress there is a strong tendency to revert to old habits.

Another aspect of the problem of rotary controls is their use to position visual indicators. This is a special case of the previously cited rule of controls moving in the direction and sense of the unit being actuated. Tests have shown that when such a knob is used to position a linear indicator there is complete ambiguity of response if the knob and indicator are in different planes. However, when the knob is mounted in the same plane as the indicator there is a highly consistent response pattern. From 70 to 95 per cent of the subjects tested turned the side of the knob adjacent to the indicator in the direction of the desired indicator motion. By projection, it can be seen that the operator in effect turned the knob clockwise to produce a clockwise indicator motion.

This same "clockwise-clockwise" tendency has been found in the use of a knob to position a semicircular indicator.[24] Here, however, it was found that some arrangements of knob and indicator evoked much more consistent response than others. With one arrangement, the number of test subjects supporting the clockwise-clockwise hypothesis was less than would be expected by chance. Apparently, the effect of certain arrangements is such that the presentation destroys the cues as to sense of motion. Thus in order to be sure that control motions are natural, consideration must also be given to the interpretation that will be put on the presentation. Here common sense is not enough, and psychological test data must be utilized.

Evaluation of Work Loads

In the foregoing sections of this paper problems of instrumentation and control have been considered, and it has been shown how specific measures can reduce pilot-error potential. These, while important, cover only one part of the problem. Most important is the overall design approach of considering the pilot and his capacities. Even though all of the measures discussed were to be utilized fully, the demands placed upon the pilot could still exceed human limitations, particularly with regard to the number of duties involved and the speed with which they must be performed.

In analyzing this problem, the use of time-motion studies is of value. Such studies were made on a multiengined aircraft that in the initial phases of operation had an extremely high incidence of landing accidents due to crew error. These studies revealed that from the time the aircraft entered the traffic pattern until it touched down, the copilot was required to make 116 distinct motions in 305 sec., an average of one every 2.6 sec. During one period of 90 sec., the required rate of movements was one every 1.8 sec.[25] Under normal conditions, a man can carry out such a routine with comparative ease. When, however, he is

under stress in an emergency, or is suffering from fatigue, an error becomes highly probable.

In evaluating crew ability to carry work load, average performance levels cannot be assumed. Full consideration must be given to day-to-day variability in performance, and to the added effect of factors such as fatigue in producing a definite deterioration in these levels.[26,27]

Reduction of Work Loads

Crew work loads can often be reduced by simplification of controls for functional systems. Although a discussion of the design of such systems is beyond the scope of this paper, it should be pointed out that the pilot must be considered in the original design concept, in order to avoid undue complexity in the controls.

When analysis of crew work load shows it to be approaching the limit of human capacity, despite all possible measures in control simplification, other steps must be taken to relieve the load. If transfer of duties to another crew member is not possible, the airplane must take over the function by means of automatic control. This, of course, implies increased complexity in the machine. However, the basic goal is a man-machine combination that can operate with maximum overall efficiency. While design simplification is highly desirable for reasons of cost, weight, and maintenance, it cannot be achieved at the expense of overloading the human element. If it is acquired in this way, the cost of resulting accidents may far overbalance the saving achieved by the simplification.

Emergency Controls

In no phase of cockpit design is full consideration of the human factor so important as in the design of emergency controls. When an emergency arises, the time available for the pilot to take the necessary action is extremely short. Emergency procedures, therefore, must not be complex. Controls must be easily identifiable and readily accessible: control motion and sequence of operation should be as simple as possible. It is imperative that all control motions be completely consonant with normal habit patterns, since, as has been established, a person tends to revert to old habits under conditions of stress.

Too frequently design engineers have the attitude that it does not matter if emergency controls are complicated or difficult to reach, since they may never be used in the life of the airplane. Far too many incidents have become accidents because of this philosophy.

Funk and Wagnalls' Dictionary defines an emergency as:

"A sudden or unexpected occurrence or condition calling for immediate action; a perplexing and pressing combination of circumstances."

The designer should at least try not to add to the pilot's perplexity.

Conclusions

Many so-called pilot errors have resulted from design that failed to consider basic human limitations. In order to eliminate such accident potential a new design philosophy is needed. Analysis of the qualities of the machine is common engineering practice; yet to maintain a sound man-machine relationship, it is also necessary to analyze the qualities of the man. Research in Human Engineering has provided the basis for implementing this approach. It remains for the designer to make full use of the available data.

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(*Concluded on page 124*)

Liquid-Coupled Regenerators for Turboprops*

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ABSTRACT

Because of its better take-off thrust characteristics, coupled with good fuel economy, the turboprop plant will undoubtedly be developed to a stage where it will supplant the turbojet engine in some degree. This substitution will be noted more particularly for low-speed (less than 500 m.p.h.) long-range (greater than 3,000 miles) aircraft.

The natural trend of the turboprop development appears to be in the direction of higher pressure ratios because of improved specific fuel consumption. It is the purpose of this paper to point out, however, that the low pressure ratio regenerator-turboprop development should also be seriously considered.

Cycle studies demonstrate that the regenerator-turboprop system can realize a plant fuel economy comparable to that of modern reciprocating aircraft power plants, and design studies indicate that the regenerator can be of moderate weight. However, the resulting complexity and size of the additional ducting, when using a conventional *direct-transfer* regenerator, destroys the aerodynamic advantages of small frontal area. In contrast, the *liquid-coupled indirect-transfer* regenerator allows a straight-through flow system from the compressor intake to the tailpipe, as in the simple turboprop system. This results from the use of two heat exchangers coupled by a liquid heat-transfer medium for transporting the thermal energy from the turbine exhaust gases to the compressor air just prior to the combustion process. The resulting power plant is aerodynamically clean with a small frontal area, and the components are accessible for servicing.

The design studies in this paper indicate that such a regenerator can be constructed for moderate pressure drops and for a specific weight of less that 0.3 lb. per s.hp. Against this, the advantage of an improvement of 0.10 lb. per s.hp.-hr. in fuel economy can be weighed.

The ultimate realization of this type of regenerative turboprop plant depends upon the development of a suitable coupling liquid. Current work on liquid metals as a heat-transfer medium in nuclear power plants holds promise for the future in this respect.

NOMENCLATURE

English Letter Symbols

A	=	heat-transfer area, sq. ft.
C	=	flowstream thermal capacity rate, (Wc_p), B.t.u./(hr. °F.)
c_p	=	gas specific heat at constant pressure, B.t.u./(lb. °F.)
G	=	flow mass velocity, lbs./(hr. ft.² of minimum flow cross section)
h	=	unit convective heat-transfer conductance, B.t.u./(hr. ft.² °F.)
h	=	enthalpy, B.t.u./lb.
k	=	thermal conductivity, B.t.u./(hr. ft.² °F./ft.)
P	=	pressure, lbs. per sq.ft.
P^*	=	gas-turbine compressor pressure ratio
r_h	=	flow passage hydraulic radius, ft.
s	=	entropy, B.t.u./(lb. °R.)
T	=	temperature, °R.
t	=	temperature, °F.
U	=	unit overall heat-transfer conductance, B.t.u./(hr. ft.² °F.)
V	=	velocity, ft./sec.
v	=	specific volume, ft.³/lb.
W	=	mass flow rate, lbs./hr.

Greek Letter Symbols

α	=	heat-transfer area per unit of core volume, ft.²/ft.³
δ	=	fin thickness, in.
Δ	=	on P, denotes inlet minus outlet pressure difference, lbs./ft.²
ϵ	=	exchanger effectiveness, the actual heat-transfer rate divided by the maximum possible heat-transfer rate
ϕ	=	a functional relationship
η_0	=	overall temperature effectiveness of a fin-type heat-transfer surface
η	=	(with subscripts other than 0) efficiency
ρ	=	density, lbs./ft.³
σ	=	ratio of free flow to frontal area
μ	=	viscosity, lbs./(hr. ft.)

Nondimensional Groupings

NTU	=	number of heat-transfer units, (AU/C)
NTU^*	=	NTU_c/NTU_h
Re	=	flowstream Reynolds Number based on the hydraulic diameter $4r_h$, and the velocity at the minimum flow cross section
Pr	=	Prandtl Number, $(\mu c_p/k)$

Subscripts

a	=	air side
c	=	cold side or cold unit
c	=	(on η) compressor
cc	=	combustion chamber
g	=	gas side
h	=	hot side or hot unit
j	=	nozzle
L	=	coupling liquid
0	=	overall hot unit plus cold unit
t	=	turbine
th	=	overall thermal
1	=	inlet conditions
2	=	outlet conditions

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INTRODUCTION

THE TURBOPROP IS the second major accomplishment in the development of the gas-turbine plant as an aircraft prime mover. The turbojet has the

advantages of greater simplicity and lower weight, but in terms of specific fuel consumption it has relatively poor performance. Moreover, the take-off thrust is much inferior to a propeller engine, and, consequently, either long runways or some form of assist take-off is required. These factors make the turboprop an attractive power plant for the long-range planes of the immediate future.

Since operational turboprop engines may be expected shortly, it is worth while to consider future developmental trends for this system which will result in further gains in fuel economy. The "natural" trend appears to be in the direction of higher pressure ratios—of the order of 20:1 as compared to 7:1 in current plants. However, another line of development which does not require high pressure ratios, is the regenerator-turboprop engine.

Tubular *direct-transfer-type* regenerators have been built for stationary, locomotive, and marine gas turbines, but the volume and weight of these regenerators is prohibitive when considered for application to the aircraft turboprop. Although the use of compact heat-transfer surfaces in direct-transfer regenerators can result in much lighter and more compact units,[1] it is questionable whether this type of regenerator will ever be practical for the turboprop application. The compact heat-transfer surfaces generally result in awkward regenerator core shapes, and the direct-transfer regenerator will always require that the compressed air from the compressor be ducted back behind the turbine to meet the exhaust gases or vice versa. While this latter point is not necessarily objectionable for the stationary or even the locomotive and marine plants, it tends to destroy the advantage of small frontal area in the turboprop, and to introduce serious flow losses due to the fairly sharp bends that would be necessary in the ducting.

A distinct possibility for a practical regenerator for the turboprop system is an *indirect-transfer rotary-type* heat exchanger similar in principle to the Ljungstrom air preheater, where a rotating drum containing a heat-transfer matrix is alternately heated by the exhaust gases and cooled by the compressed air entering the combustion chambers.[2] The advantage of this system stems from the fact that an extremely compact, large heat-transfer area matrix can be easily constructed which will not necessarily result in an awkward core shape. Further, the periodically reversed flow in the matrix will provide a self-cleaning feature. The rotary type promises an extremely lightweight regenerator, as compared with the possibilities with the direct-transfer type, but this system still suffers from the forementioned ducting disadvantages that result in a large frontal area for the complete plant.

Another possibility, and the main subject of this paper, is an indirect-transfer regenerator consisting of separate exhaust gas cooler and compressed air heater components coupled by a liquid heat-transfer medium—the *liquid-coupled indirect-transfer-type* regenerator.[3] The principle involved is not new, and two common examples are the engine-block-radiator combination of the liquid-cooled automotive engine and the steam-boiler-radiator combination used for space heating. The Ljungstrom rotary air preheater, previously mentioned, where the drum rotation provides a "flow" of solid phase metal as a coupling medium from the hot gas to the cold gas sides, is a special case of this same general system.

In reference 4 the liquid-coupled system was considered for application to stationary and transportation-type prime movers and was shown to be competitive with direct-transfer-type regenerators from the point of view of core weight and volume. In addition, it possesses the following advantages:

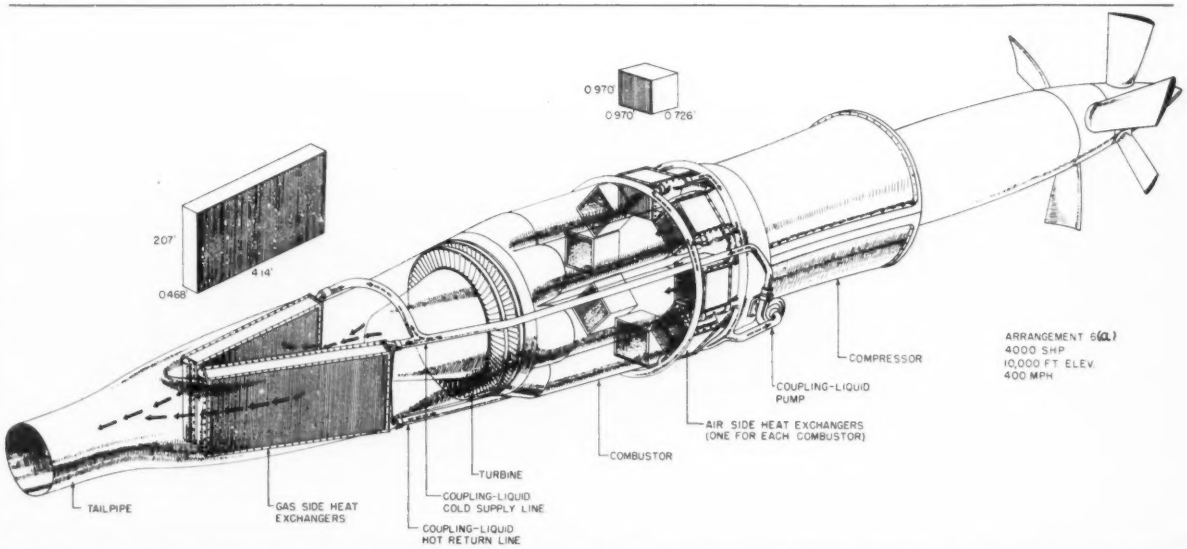

FIG. 1. Application of liquid-coupled regenerator: 4,000 s.hp.; 6:1 pressure ratio; 10,000 ft. elevation; 400 m.p.h. Interrupted plate-fin Surface Arrangement 6 (Fig. 7). Designs Nos. 11 and 12 (Table 5 and Fig. 8).

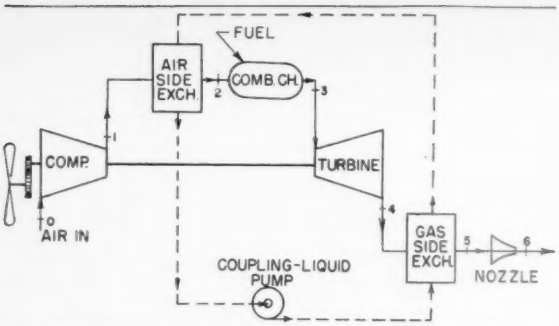

FIG. 2. Liquid-coupled regenerator-turboprop flow diagram.

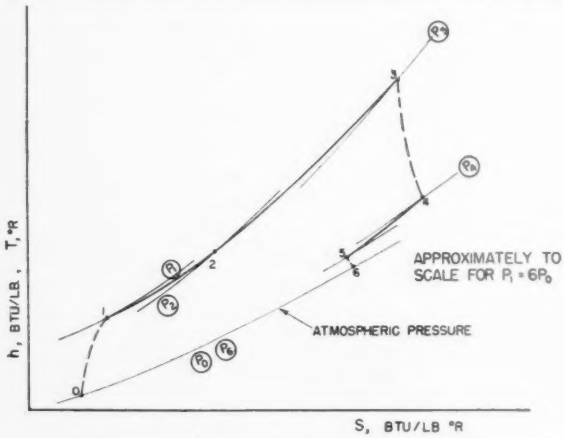

FIG. 3. Process representation for regenerator-turboprop enthalpy-entropy and temperature-entropy planes. (See Fig. 1 for numbered state designations.)

(1) The air and gas flowstream frontal areas may be shaped independently of one another. Since there is at least a 6:1 disparity in the air and gas side densities, the use of compact heat-transfer surfaces results generally in awkward regenerator core shapes for the direct-transfer arrangement.

(2) A considerable simplification of air ducting and header construction results because it is not necessary to bring the cold air over to the turbine exhaust stack and then back to the combustion chambers.

(3) If extended transfer surfaces are used, as is desirable from the point of view of compactness, it is only necessary to have fins on one side of the surface.

(4) It is possible to use a multiplicity of small units that may simplify manufacture, cleaning, and servicing and reduce the stress problems arising from thermal expansions.

(5) Closer approach to counterflow characteristics can be realized without suffering a penalty in shape.

It is item (2) that affords the greatest attraction in the aircraft turboprop application. Fig. 1 shows an example of a liquid-coupled indirect-transfer regenerator incorporated in a turboprop system. The simplification in the air and gas ducting is apparent as the straight-through flow feature of the simple gas turbine is maintained and no increase in power-plant frontal area results.

TABLE 1
Turboprop Cycle Operating Conditions

Altitude, 10,000 ft.
Ambient air state,
t_0, 23.3 °F.
P_0, 10.10 lbs. per sq.in. } N.A.C.A. Std. Atmosphere
Air speed, 400 m.p.h. = 587 ft. per sec.
Ram and compressor combined efficiency, $\eta_c = 0.82$
Combustion efficiency, $\eta_{cc} = 0.97$
Turbine efficiency, $\eta_t = 0.85$
Nozzle efficiency, $\eta_j = 0.95$
Turbine inlet temperature, $t_3 = 1{,}540$ °F.
Regenerator air side pressure drop, $(\Delta P/P_1)_a \approx 2\%$
Regenerator gas side pressure drop, $(\Delta P/P_1)_g \approx 4\%$
Combustion chamber pressure drop, $(\Delta P/P_1)_{cc} = 5\%$
Propulsion efficiency of jet, 80–85% ($\cong$ Propellor Efficiency)
Regenerator overall effectiveness, $\epsilon = 0.50$
Fuel, kerosene, H/C† = 0.18, $LHV_0 = 18{,}400$ B.t.u. per lb.

† H/C denotes hydrogen : carbon ratio.

In contrast to the above advantages, the disadvantages of the liquid-coupled indirect-transfer type are:

(1) The requirement of a "good" liquid heat-transfer medium for coupling the hot and cold exchanger units.

(2) A greater total transfer area (by about 5–10 per cent) because of the thermal resistance of the liquid sides of both exchangers.

(3) A somewhat larger and heavier shell structure requirement—i.e., two smaller heat exchangers versus one larger exchanger.

(4) The addition of a flow circuit to the gas-turbine plant for the circulation of the coupling liquid.

No satisfactory liquid heat-transfer medium is in common use today, although current work with the liquid metals holds considerable promise for the future.[5] The requirements for the coupling liquid are as follows: (a) low freezing point (less than 40°F.); (b) high boiling point (above 1,000°F. for moderate pressures); (c) low density, low viscosity, and high thermal conductivity; (d) high heat-transfer coefficient, of the order of 2,000 B.t.u./(hr. ft.^{2} °F.) for moderate flow velocities; (e) chemical stability; and (f) ease of handling in pumps and piping systems. Some of the alloys of sodium and potassium possess these characteristics to a high degree, but because of their reactivity with air, special handling techniques must be employed.

It is the purpose of this paper to demonstrate that the liquid-coupled indirect-transfer regenerator may provide a practical solution to the problem of a regenerator for the aircraft turboprop system, provided that a suitable coupling liquid becomes available and that manufacturing techniques can be developed for the construction of heat exchangers for high-temperature service employing compact heat-transfer surfaces. This objective will be accomplished by presenting a number of designs of regenerators employing various heat-transfer surfaces for a typical aircraft turboprop cycle. No attempt was made to closely optimize the cycle with respect to the magnitudes of regenerator effectiveness and pressure drop employed relative to the weight of the regenerator. These designs should, therefore, be considered not as proposals for actual construction

TABLE 2
Summary of Cycle Performance†

	$P^* = 5$	$P^* = 6$	$P^* = 7$	$P^* = 8$
η_{th}	27.0 (22.0)	28.2 (23.5)	29.1 (24.7)	29.1 (25.4)
Lbs. fuel/lb. air	0.01285 (0.01818)	0.01297 (0.01747)	0.01305 (0.01685)	0.01306 (0.01628)
W, lbs. air/1,000 s.hp.-hr.	39,900 (34,560)	37,880 (33,610)	36,480 (33,220)	36,400 (33,500)
Specific Fuel Consumption, lbs. per s.hp.-hr.	0.513 (0.628)	0.492 (0.588)	0.476 (0.560)	0.476 (0.545)
Nozzle Power: Total Power	0.218 (0.185)	0.205 (0.170)	0.196 (0.163)	0.197 (0.154)
Jet Velocity, ft. per sec.	834 (823)	832 (809)	828 (784)	832 (773)
‡Regenerator Air Side:				
P_1, lbs. per sq.in.	50.50	60.65	70.75	80.8
t_1, °F.	364.5	413.5	456.2	495.1
t_2, °F.	725.9	718.4	712.4	712.0
‡Regenerator Gas Side:				
P_1, lbs. per sq.in.	12.64	12.64	12.64	12.64
t_1, °F.	1,058.4	1,000.9	960.3	915.3
t_2, °F.	718.8	712.4	707.4	707.8

(Figures in parentheses indicate performance without regeneration)

† See Fig. 4 for a graphical presentation of these results.
‡ See Fig. 2, the flow diagram, for the meaning of the subscripts on the state functions.

but merely as illustrations of the possibilities inherent in the liquid-coupled system.

CYCLE OPERATING CONDITIONS

Fig. 2 is a flow diagram of the system under consideration. The cycle conditions are shown on the usual thermodynamic coordinates, Fig. 3. Table 1 gives the operating conditions and specifications that have been assumed. These do not apply specifically to any particular system but are representative of what is typical of present-day practice. The air speed of 400 m.p.h. was chosen, since this is in the speed range generally conceded to be best suited to the turboprop application—between optimum speed for the reciprocating engine and the turbojet. The altitude of 10,000 ft. was chosen arbitrarily and fixed the ambient conditions as determined from the N.A.C.A. standard atmosphere.

The ram efficiency is considered to be included in the assumed compressor efficiency. Additionally, it is specified that the exhaust gases be allowed to expand to a velocity that will yield a jet propulsion efficiency approximately equal to the propeller efficiency. The result is a jet velocity of about 825 ft. per sec., attained by increasing the regenerator back pressure with a nozzle. This procedure gives optimum jet propulsive efficiency and has the further advantage of allowing the gas-side regenerator component to operate at a moderately higher gas density, resulting in a hot-side exchanger of smaller size and weight. A more complete analysis may indicate that overcompensation in this respect is desirable in order to yield a lighter regenerator, especially at extremely high altitudes where the exhaust density at the pressure of the atmosphere will be small.

Mechanical efficiency of the propeller reduction gears is taken as 100 per cent, and the power required by such auxiliaries as the fuel pump, lube oil system, generator, etc., is neglected. However, if desired, an overall mechanical efficiency to include the reduction gear efficiency and the auxiliary power may be applied directly to the shaft horsepower quoted for the various regenerator designs.

The choice of overall regenerator effectiveness and pressure drop may not be optimum with respect to each other and to the various regenerator designs. However, these magnitudes are of the same order as chosen in reference 2 after extensive analysis of the application of the regenerator to the turboprop system.

The cycle was analyzed employing the air and combustion products properties of reference 6. The results of this analysis for various pressure ratios are given in Table 2 and on Fig. 4, along with the performance of the same system without the regenerator.

A pressure ratio of 6:1 was chosen, for the purpose of making specific regenerator designs, as being typical of present practice, although it should be noted that this pressure ratio is not the optimum for operation either with or without the regenerator. However, one of the advantages of regeneration is evident in this regard, since the optimum pressure ratio is lower with regeneration than without. Also the efficiency curve is "flatter," indicating better part-load characteristics. Table 3 gives the operating conditions for the regenerator at a pressure ratio of 6:1, along with the fluid properties at these conditions, from reference 7.

More comprehensive studies of aircraft gas-turbine cycles, including range and weight considerations, are available in references 8 and 9.

THEORY OF THE LIQUID-COUPLED INDIRECT-TRANSFER REGENERATOR

The complete analysis of the liquid-coupled indirect-transfer heat exchanger is given in reference 4. In-

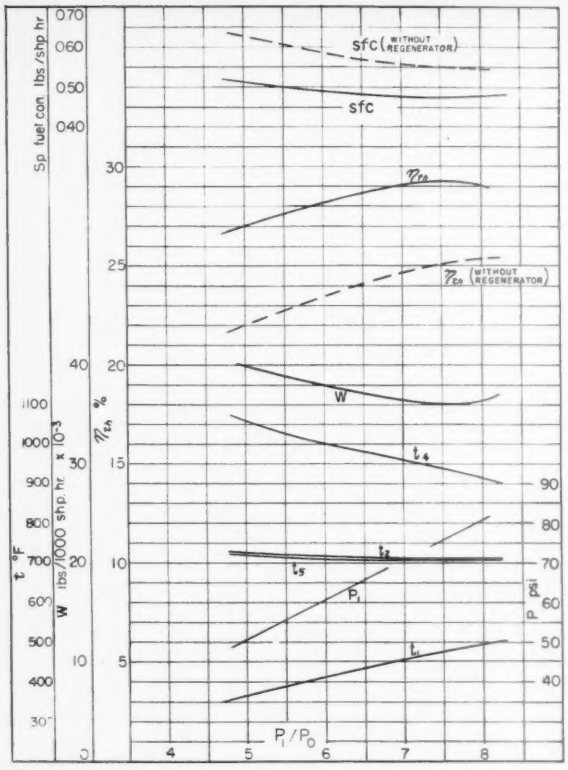

FIG. 4. Thermodynamic performance of regenerator-turboprop system (See Table 1 for basis.)

cluded here is a brief summary of the results of this analysis and a discussion of the application to the special case of gas-turbine regenerator.

The effectiveness, ϵ, of a heat exchanger is, by definition, the ratio of the actual heat-transfer rate to the maximum possible heat-transfer rate. This maximum would be realized in a counterflow heat exchanger of infinite transfer area operating with the same flow rates and fluid temperatures as the exchanger in question. It may be shown that

$$\epsilon = \phi(NTU_{max.}, C_{min.}/C_{max.}, \text{flow arrangement})$$

where $NTU_{max.} = AU/C_{min.}$. In reference 10 this functional relationship is given graphically for a number of different flow arrangements for direct-transfer exchangers. Fig. 5 shows the ϵ-NTU relationships for the multipass cross-counterflow arrangements considered for these design studies for the particular case of $C_{min.}/C_{max.}$ = unity.

The liquid-coupled indirect-transfer heat exchanger is a combination of two conventional direct-transfer heat exchangers. The *overall effectiveness* of the coupled system is expressible in equation form as a function of the effectiveness of each of the components and the relative flowstream capacity rates (flow rate times specific heat). The purpose of this section is to consider the reduced form that these equations[4] assume for the special case of equal capacity rates, as is closely realized in the gas turbine regenerator system. These expressions are then analyzed to ascertain optimum conditions with respect to (a) coupling-liquid circulation rate and (b) distribution of total transfer area between the hot and cold exchanger components.

For the case of the gas-turbine regenerator, $C_h \approx C_c$, and for $C_L \geq C$,

$$\epsilon_0 = 1/[(1/\epsilon_c) + (1/\epsilon_h) - (C/C_L)] \quad (1)$$

for $C_L \leq C$,

$$\epsilon_0 = (C_L/C)/[(1/\epsilon_c) + (1/\epsilon_h) - 1] \quad (2)$$

where $C = C_c = C_h$, the capacity rate of both the hot gas and cold air streams. C_L is the coupling-liquid capacity rate (flow rate times specific heat capacity), an independent variable that may be controlled as desired. Inspection of Eqs. (1) and (2) reveals that, for any given magnitudes of the component heat transfer effectivenesses, ϵ_c and ϵ_h, for the cold and hot exchangers, respectively, the overall effectiveness ϵ_0 is maximized by making $C_L = C$. This same conclusion is demonstrated graphically in Fig. 6a, where ϵ_0 is plotted as a function of C_L/C. However, the optimum point is not so critical as depicted in Fig. 6a because, for given transfer areas A_h and A_c and overall heat-transfer coefficients U_h, U_c in the two heat exchangers, a modification of C_L will also influence the component effectivenesses ϵ_h and ϵ_c in a manner that tends to com-

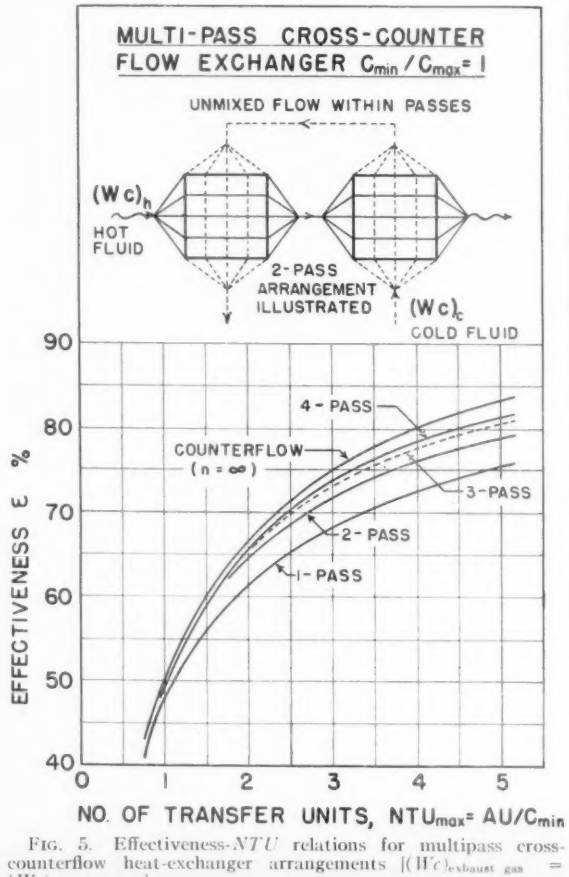

FIG. 5. Effectiveness-NTU relations for multipass cross-counterflow heat-exchanger arrangements [$(Wc)_{\text{exhaust gas}} = (Wc)_{\text{compressed air}}$].

TABLE 3
Regenerator Operating Conditions at 6:1 Pressure Ratio

	Air Side	Gas Side
Inlet to Regenerator		
P_1, lbs. per sq.in.	60.65	12.64
t_1, °F.	414	1,001
v_1, ft.³/lb.	5.34	42.8
Average Properties		
$P_{av.}$, lbs. per sq.in.	60.1	12.38
$t_{av.}$, °F.	566	857
c_p, B.t.u./lb. °F.	0.249	0.259
μ_f, lbs./hr. ft.	0.0745	0.0804
Pr_f	0.667	0.663
Specific Flow Rate, lbs./1,000 s.hp.-hr.	37,880	38,360
Capacity Rate Ratio, C_a/C_c	0.950	

pensate to a certain extent the reduction of ϵ_0 caused by the variation of C_L. This conclusion is most readily demonstrated graphically, as shown in Fig. 6b for the case of counterflow exchanger components with $NTU_h = NTU_c$. It can be seen that a coupling liquid flow rate 20 per cent in excess of the optimum ($C_L/C = 1.20$) will not seriously decrease the overall effectiveness. However, a decrease of 20 per cent ($C_L/C = 0.80$) below the optimum results in a significant decrease in ϵ_0.

With C_L/C = unity, as required for optimum performance, Eqs. (1) and (2) reduce to

$$\epsilon_0 = 1/[(1/\epsilon_c) + (1/\epsilon_h) - 1] \qquad (3)$$

The component exchanger effectivenesses are independent variables, and the question remains as to what particular combination of ϵ_c and ϵ_h will maximize the overall effectiveness for a given total heat-exchanger size and weight. This question can be answered completely only by comparing various actual designs. However, the following considerations will yield a qualitative criterion for the distribution of total heat-transfer surface between the two exchanger units. For a specified flow arrangement—i.e., counterflow, cross flow, etc.—the component effectivenesses ϵ_c, ϵ_h are unique functions of NTU_c and NTU_h, respectively, for the condition of $C_c = C_h = C_L = C$. Fig. 5 reveals this relation for several flow arrangements. For the case of true counterflow, however, a graphical representation is not necessary, since the algebraic expression is, simply,

$$\epsilon = NTU/(1 + NTU) \qquad (4)$$

Substitution into Eq. (3) yields

$$\epsilon_0 = NTU^*NTU_0/(1 + NTU^*)^2 + NTU^*NTU_0 \qquad (5)$$

where

$$NTU_0 = NTU_h + NTU_c \text{ and } NTU^* = NTU_c/NTU_h = A_cU_c/A_hU_h$$

If NTU_0 is maintained constant, the usual method of limits reveals that ϵ_0 is a maximum when NTU^* is unity. Should the conductances U_c and U_h in the cold and hot exchangers, respectively, happen to be essentially the same, then a constant NTU_0 corresponds to the condition of constant total area $A_0 = A_h + A_c$, and the optimizing condition of NTU^* = unity corresponds to an equal area distribution $A_h = A_c$. However, for the designs considered in this paper, U_c/U_h is in the range 1.3 to 1.9 (see Table 5), and, for these conditions, holding NTU_0 a constant does not correspond to holding total transfer area a constant. The question as to optimum area distribution is then not answered by the specification of NTU^* = unity.

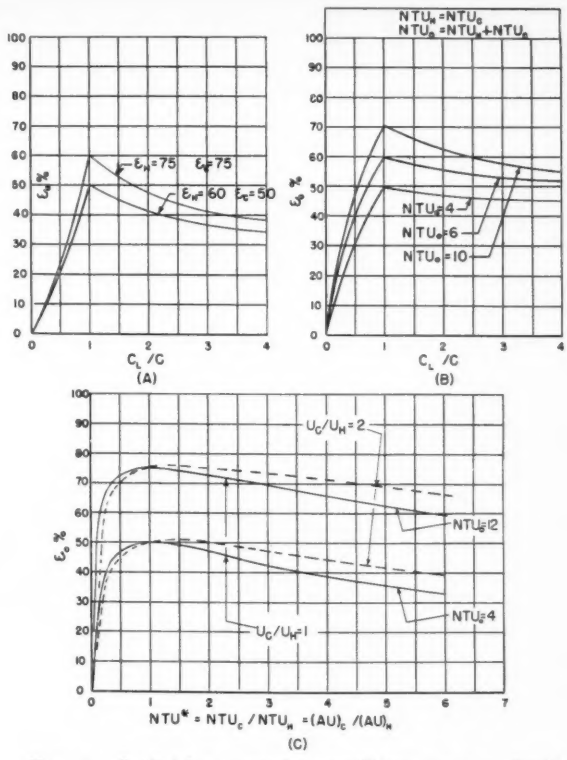

FIG. 6. Optimizing operating conditions for the liquid-coupled regenerator. Optimizing conditions for coupling-liquid flow rate with ϵ_0 as a parameter. Optimizing conditions for coupling-liquid flow rate with NTU_0 as a parameter. Optimizing conditions for transfer area distribution for $U_c/U_h = 1$ and 2.

To examine this point in more detail, Eq. (5) was graphed as ϵ_0 versus NTU^*, Fig. 6c (solid lines), for two magnitudes of NTU_0 corresponding to maximum overall effectivenesses of 50 and 75 per cent, respectively. Then, employing Eqs. (3) and (4) and the arbitrary specification of $U_c/U_h = 2$, ϵ_0 versus NTU^* ($= 2A_c/A_h$ in this case) was calculated for the specification of two magnitudes of constant total area A_0. The magnitudes of A_0 were selected so as to pass the two curves (dashed lines) through the points ($\epsilon_0 = 0.75$, $NTU^* = 1$) and ($\epsilon_0 = 0.50$, $NTU^* = 1$). It is seen from this result, Fig. 6c, that $U_c/U_h > 1$ shifts the optimum area distribution to larger than unity magnitudes of NTU^*. However, because the curve is flat in the region of maximum ϵ_0 and since the design U_c/U_h is in the range 1.3 to 1.9, it can be concluded that an area distribution corresponding to NTU^* within the range 0.75 to 2.00 will yield close to maximum overall effectiveness. That is, A_c/A_h in the range $0.75/(U_c/U_h)$ to $2/(U_c/U_h)$ is the criterion for optimum heat-transfer area distribution.

TABLE 4

HEAT TRANSFER SURFACES

ARRANGEMENT	1	2	3	4	5	6(a)	6(b)	6(c)
Surface No.	ST-1	FTD-2	11.32-.737-SR	19.86	17.8-3/8R	1/8-15.2	1/8-15.2	1/8-15.2
Type	Inside Circular Tubes	Over Banks of Dimpled Flattened Tubes	Finned-Flat Tubes	Plain Plate-Fin	Wavy Plate - Fin	Interrupted Plate-Fin	Interrupted Plate-Fin	Interrupted Plate-Fin
$4\,r_h$, ft.	0.01925	0.0160	0.01153	0.00598	0.00696	0.00868	0.00868	0.00868
σ	0.530	0.422	0.760	0.671	0.776	0.671	0.671	0.671
α, ft^2/ft^3	110.2	121.9	270	449	446	362	362	362
Fin Area/Total Area	---	---	0.845	0.849	0.892	0.873	0.873	0.873
Fin Thickness, δ, in.	---	---	0.004	0.006	0.006	0.006	0.006	0.006
Wall Thickness, in.	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Specific Wt, lbs/ft^3	27.0	29.9	28.9	63.3	60.5	50.0	55.8	25.1
Liquid Side Area, α_L, ft^2/ft^3	116	110	42	68	48	52	52	52
Liquid Space Width, in.	---	0.132	0.088	0.050	0.050	0.050	0.050	0.050
Effective Fin Length, in.	---	---	0.225	0.125	0.207	0.207	0.207	0.207
Wall Material	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel
ρ, lbs/ft^3	490	490	490	490	490	490	490	490
K, Btu/hr ft^2 °F/ft.	25	25	25	25	25	25	25	25
Fin Material	Steel	Steel	Steel	Steel	Steel	Steel	Copper	Aluminum
ρ, lbs/ft^3	490	490	490	490	490	490	555	175
K, Btu/hr ft^2 °F/ft.	25	25	25	25	25	25	210	140

TABLE 5

SUMMARY OF DESIGN RESULTS

Design No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Side	Air	Gas	Air	Gas	Air	Gas	Air	Gas	Air	Gas	Air	Gas	Air	Gas	Air	Gas	Air	Gas
Surface Arrangement	1	1	2	2	3	3	4	4	5	5	6(a)	6(a)	6(a)	6(a)	6(b)	6(b)	6(c)	6(c)
NTU Division	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Balanced	Unbalanced	Unbalanced	Balanced	Balanced	Unbalanced	Unbalanced
Volume/1000 shp, ft^3	3.69	19.0	2.42	4.76	2.66	4.12	1.30	2.11	1.25	1.67	1.36	2.00	1.68	1.54	0.764	1.32	1.84	0.767
Weight/1000 shp, lbs	99.6	513	72.3	142	76.8	119	82.3	134	74	101	68.0	100	85.9	76.6	42.7	73.7	46.2	19.8
Frontal Area/1000 shp, ft^2	1.32	4.15	2.50	5.30	1.50	3.92	1.49	3.40	1.82	4.14	1.86	4.28	2.05	3.89	1.41	4.37	1.94	3.18
Flow Length, ft	2.79	4.60	0.971	0.898	1.77	1.05	0.873	0.831	0.873	0.401	0.726	0.468	0.827	0.385	0.543	0.346	0.950	0.365
$(\Delta P/P_1)$, %	1.44	4.58	0.96	4.97	1.43	4.50	0.97	4.68	1.03	4.78	1.14	4.84	1.11	4.68	1.49	4.32	1.37	4.20
h, Btu/(hr ft^2 °F/ft)	32.4	10.8	72.6	36.4	59.3	32.9	47.2	27.8	78.6	51.9	67.4	51.2	85.0	55.2	107.2	56.2	86.1	64.0
η_o	---	---	---	---	0.524	0.650	0.885	0.865	0.552	0.688	0.541	0.639	0.851	0.685	0.858	0.920	0.855	0.871
U, Btu/(hr °F ft^2 of A)	51.6	10.6	71.0	36.0	29.2	19.9	35.9	23.3	38.3	29.7	42.6	30.4	41.3	31.9	75.8	46.2	61.6	49.3
A, ft^2/1000 shp	406	2088	295	590	718	1118	565	947	548	743	498	725	608	556	279	478	566	265
NTU	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.66	1.63	2.22	2.22	4.35	1.45
G, lbs/(hr ft^2)	54,200	17,560	55,880	17,100	32,300	12,550	37,900	16,800	26,760	11,890	25,750	11,390	23,760	12,540	34,500	12,770	24,880	15,280
V_1, ft/sec	80.3	209	53.3	203	47.9	149	56.2	200	39.7	141	38.2	136	45.7	149	50.9	152	36.9	182
R_e	14,000	4500	7700	5400	5000	1600	3000	1250	2500	1050	3000	1230	2770	1354	4000	1380	2900	1650
No. of liquid passes	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	1

Surface Arrangement #1 : Flow Inside Circular Tubes
Surface Arrangement #2 : Flow Over Banks of Dimpled-Flattened Tubes
Surface Arrangement #3 : Finned-Flat Tubes
Surface Arrangement #4 : Plain Plate-Fin
Surface Arrangement #5 : Wavy Plate-Fin
Surface Arrangement #6(a): Interrupted Plate-Fin
Surface Arrangement #6(b): Interrupted Plate-Fin with Copper Fins
Surface Arrangement #6(c): Interrupted Plate-Fin with Aluminum Fins

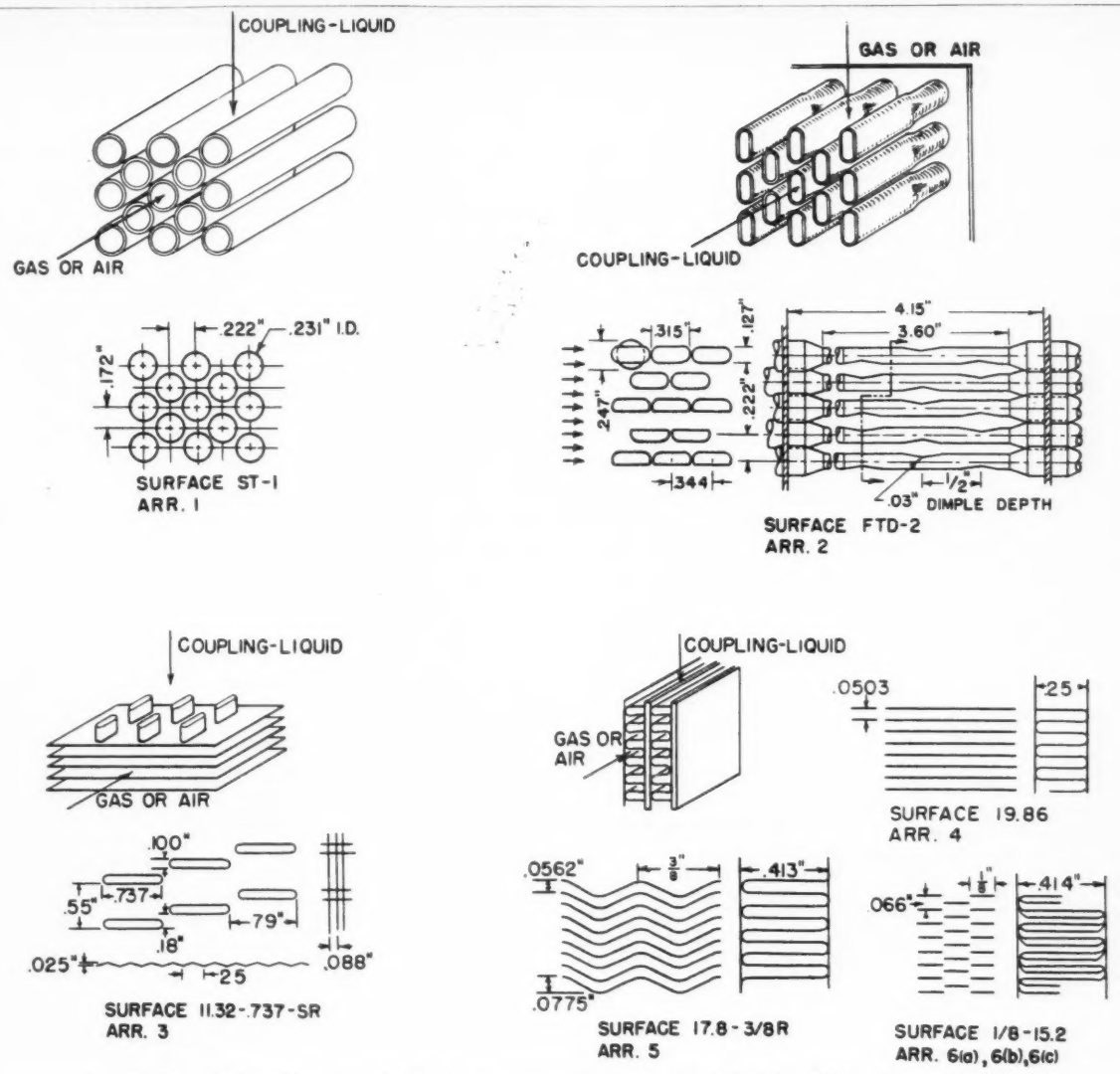

FIG. 7. Description of heat-transfer surface arrangements. (Refer to Table 4 for additional geometrical data.)

The specific selection of area distribution within this range should include a consideration of the relative costs of A_h and A_c and the geometrical requirements imposed on the regenerator by the machinery arrangement. The fact that the designer is allowed this freedom of choice without a penalty is an important advantage for this type of exchanger. Another important gain to be realized from increasing A_c relative to A_h is that the operating temperatures of the coupling liquid are reduced and, consequently, the heat exchanger surface temperatures are reduced. This might allow the use of cheaper and lighter weight materials of construction.

HEAT-TRANSFER SURFACES

The heat-transfer surfaces used for the designs presented in this study are shown on Fig. 7. For this application a surface arrangement is desired which has a large free volume and free-flow area on the gas or air side and a small free volume and free-flow area on the coupling-liquid side. This is desirable in order to minimize the dead weight of the coupling liquid in the heat exchanger. Since the pumping power requirement of a liquid tends to be small compared with that of a gas, there is no object in minimizing velocities on the liquid side.

In Arrangement 1, the gas or air flows through 0.231-in. inside diameter, closely spaced, circular tubes, and the coupling liquid flows across the tubes. The reverse arrangement with the gas or air flowing across the circular tubes does not appear practicable because of the large liquid side volume. However, the liquid side volume can be decreased by flattening the tubes, and Arrangement 2 has the gas or air flowing across a bank of flattened and dimpled tubes with the coupling liquid flowing inside.

There is a variety of finned-tube arrangements practical for this system. Arrangement 3 is representative of such surfaces and has the advantage of small coupling-liquid volume as compared with gas or air volume.

Plate-fin surfaces can be used for this application, and the desired surface arrangement characteristics can be approached by sandwiching a small coupling-liquid space between plate-fin tubes. Arrangements 4, 5, and 6 are plate-fin systems with different types of fins.

The complete geometrical specifications of the surface arrangements are given in Table 4. A core material with density and thermal conductivity comparable to mild steel was assumed for all surfaces except for the fins in Arrangements 6(b) and 6(c). A fin material with properties comparable to copper and aluminum, respectively, was chosen for these latter cases in order to investigate the advantages arising from a high thermal conductivity. Note that the coupling liquid, however, is, as in the previous cases, enveloped in steel.

The basic heat-transfer and flow friction characteristics for the gas or air sides for all of these arrangements were recently reported in reference 10. Heretofore, such studies as these would have been impossible because of the absence of adequate design data for the compact surfaces of interest in this application.

Coupling Liquids

To be useful for this application, the coupling liquid should have the following characteristics:

(1) A low freezing point (say, less than 32°F.) and a high boiling point at moderate pressures (say, greater than 1,000°F. for a pressure of less than 200 lbs. per sq.in.).

(2) A high convective heat-transfer coefficient of the order of $h_L > 1{,}000$ B.t.u./(hr. ft.^{2} °F.) for velocities less than 20 ft. per sec.

(3) A low specific gravity.

(4) A low viscosity.

(5) Ease of handling in piping and pump systems without insurmountable problems of gland sealing and corrosion.

Such standard transfer liquids as water and Dowtherm are ruled out on the basis of items (1) and/or (2). Mercury is reasonably acceptable in every respect except item (3). The high specific gravity of mercury might be acceptable in a stationary or transportation-type prime mover, but it would not be acceptable in the aircraft turboprop application. A liquid metal alloy of close to eutectic proportions of sodium and potassium has desirable characteristics with respect to the first four requirements. Its handleability is largely a matter of conjecture, but its possible use in the atomic-energy program may result in rapid developments in this respect.

Reference 5 contains the most up-to-date information on liquid metals with respect to properties, heat-transfer characteristics, and what is known about the problems of constructing circulation systems.

For the purposes of this paper, it is not necessary to know h_L accurately, since, if $h_L > 1{,}000$, the controlling thermal resistance is on the gas or air side of the heat-exchanger components. For all the designs, $h_L = 3{,}000$ B.t.u./(hr. ft.^{2} °F.) was selected. If sodium-potassium is employed as the coupling liquid, h_L may be considerably greater than this so that the designs might be considered slightly conservative. To estimate the necessary piping sizes for the circulating liquid, a specific heat per unit of volume of $\rho c = 25$ B.t.u./(ft.^{3} °F.) is used, corresponding to the properties of the sodium-potassium eutectic alloy at 700°F.

Design Method

Basic heat-transfer and flow friction design data for the surfaces employed were obtained from reference 10. For the purpose of simplifying the calculations, the following conditions were postulated for all designs except Nos. 13, 14, 17, and 18:

(1) $C_c = C_h = C_L = C$.

(2) $NTU_c = NTU_h = NTU$.

(3) $h_L = 3{,}000$ B.t.u./(hr. ft.^{2} °F.).

(4) Hot and cold components are cross-counterflow units with two passes on the coupling-liquid side.

(5) Gas and air properties and operating conditions are as specified in Table 3, with the exception that $C_{\text{air}}/C_{\text{gas}}$ = unity was used in accordance with item (1) above.

For design Nos. 13, 14, 17, and 18, NTU_c was taken as greater than NTU_h in accordance with the previous discussion regarding optimum area distribution between hot and cold components, and for design Nos. 17 and 18, four liquid passes were employed on the air side and one on the gas side.

On the basis of items (1) and (2), $\epsilon_c = \epsilon_h$ and Eqs. (1) and (2) reduce to

$$\epsilon_0 = 1/[(2/\epsilon) - 1] \tag{6}$$

where the cold and hot components have the same effectiveness (as given in Fig. 5)

$$\epsilon = \phi(NTU = AU/C)$$

For a given overall effectiveness ϵ_0, the component effectivenesses $\epsilon_c = \epsilon_h = \epsilon$ are determined. This fixes the magnitude of the necessary number of transfer units for the specified cross-counterflow arrangement for each of the components. Then, by a method of successive approximations, the core geometry is established which will give the necessary AU product with the moderate per cent pressure drop as specified in Table 1. The flow friction distribution, $(\Delta P/P_1)_{\text{air}}$: $(\Delta P/P_1)_{\text{gas}}$, was taken as approximately 0.25 at the full load design conditions, since this distribution tends to reduce the total part load frictional losses. This design criterion also has the advantage of reducing the volume and frontal area of the hot gas component (at the expense of a larger cold air component).

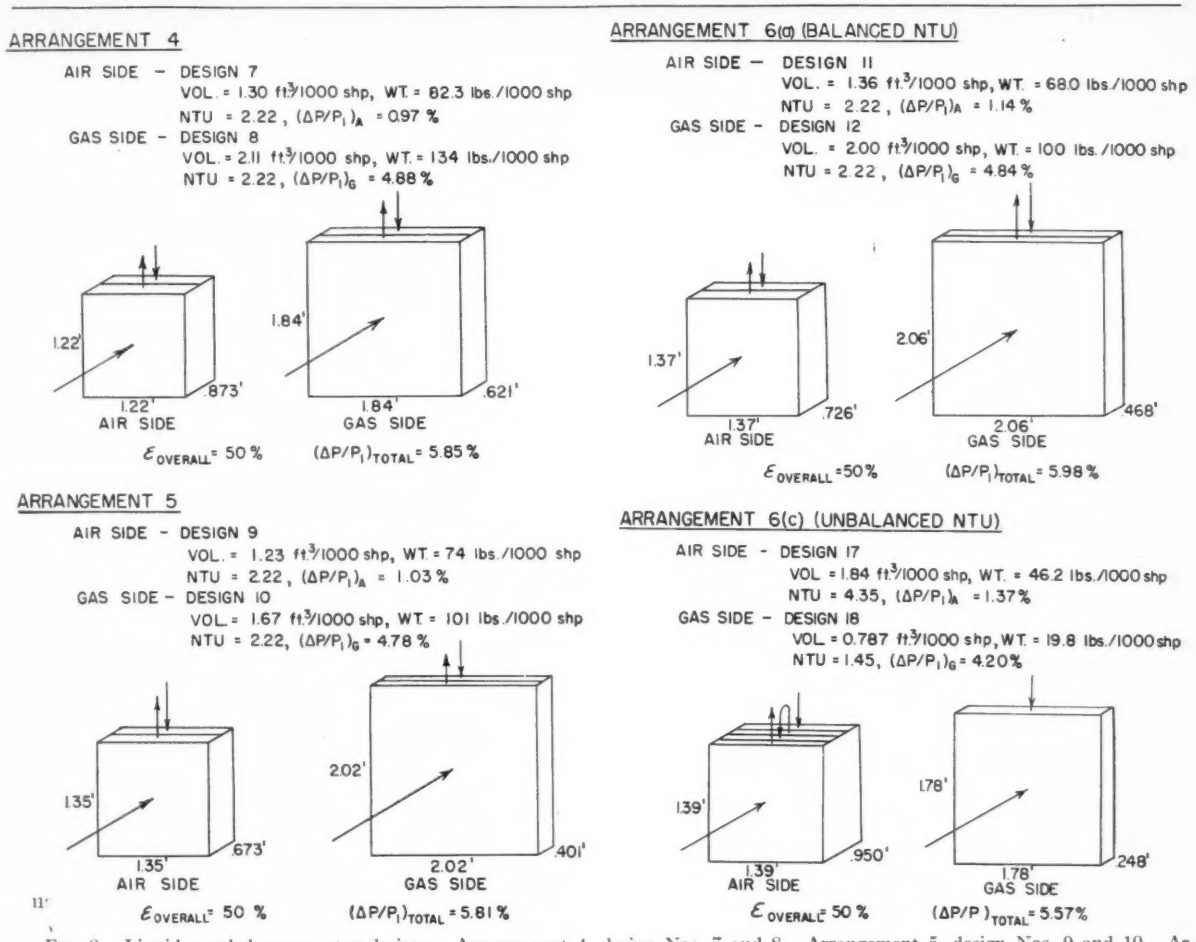

FIG. 8. Liquid-coupled regenerator designs. Arrangement 4, design Nos. 7 and 8. Arrangement 5, design Nos. 9 and 10. Arrangement 6(a), design Nos. 11 and 12 (see Fig. 1 for application of this design). Arrangement 6(c), design Nos. 17 and 18. More details on these and ten other designs are summarized in Table 5.

REGENERATOR CORE SHAPES

The foregoing considerations, together with the basic heat-transfer and flow friction characteristics of the surface arrangements shown on Fig. 7, were used to design 18 heat exchangers—nine for the compressed air side component and nine for the exhaust gas side component. An air and a gas side component was designed using each of the six surface arrangements. Then six additional designs were made using variations of Surface Arrangement 6. A complete summary of the designs is given in Table 5.

The several designs shown on Fig. 8 are all for a 1,000 s.hp. plant. The heat-exchanger requirement for a larger plant is obtained by scaling up the frontal area of each component in direct proportion to the plant capacity. The air or gas flow length remains unchanged. These drawings all show a square frontal area, but one of the advantages of the liquid-coupled arrangement is that a considerable variation in frontal area is possible without changing heat-transfer performance. The only parameter varied is the liquid velocity and, thus, the liquid pumping requirement, which is small in the first place. It should also be noted that the regenerator components need not be single units but can be built up of smaller units in a number of ways. Fig. 1, showing the application of designs Nos. 11 and 12 to a 4,000 s.hp. turboprop system, is an example in which the hot and cold component units are each built up of a number of smaller units in parallel, arranged to best fit the machinery layout.

Of primary importance in the turboprop application is the weight of the overall regenerator assembly. A summary of the weights of the heat-exchanger cores (gas side plus air side components) is given in Table 6, together with the core volumes. The weight of the coupling liquid and of the headers, piping, pump, etc., must be added to arrive at a realistic estimate of the total to be charged to the regenerator. For the designs shown, if a liquid of approximately 50 lbs. per cu.ft. density is employed (corresponding to a Na-K alloy), the total liquid weight will be of the order of 0.10 lb. per s.hp. for the designs employing Surface Arrangements 4, 5, and 6. The liquid weight will be somewhat greater for Surface Arrangements 1, 2, and 3 because of the larger core volumes.

Surface Arrangement 1, Fig. 7, flow inside 0.231-in. circular tubes, yields a weight and also volume which

TABLE 6
Total Volumes and Weights Air Side Plus Gas Side

Design Nos.	Surface Arrangement	Volume / 1,000 s.hp., ft.³	Weight / s.hp., lbs.
1, 2	1	22.7	0.613
3, 4	2	7.18	0.214
5, 6	3	6.78	0.196
7, 8	4	3.41	0.216
9, 10	5	2.90	0.175
11, 12	6(a)	3.36	0.168
13, 14	6(a) Unbal. *NTU*	3.22	0.161
15, 16	6(b) Bal. *NTU* (Cu fins on steel)	2.30	0.116
17, 18	6(c) Unbal. *NTU* (Al fin on steel)	2.63	0.066

Using liquid Na-K alloy, the liquid weight (including liquid in piping and headers) will be of the order of 0.10 lb. per s.hp.

TABLE 7
Liquid and Solid Metal Peak Temperatures (Surface Arrangement 6)

Design No.	Surface	Liquid Peak† Temperature, °F.	Fin Metal Peak Temperature, °F.
12	1/8-15.2	854	942
14	1/8-15.2 (Unbal. *NTU*)	827	936
16	1/8-15.2 (Cu fins)	854	875
18	1/8-15.2 (Al fins and unbal. *NTU*)	772	824

† These temperatures are for a turbine exhaust gas temperature of 1,000°F. and a compressor air discharge temperature of 414° F., see Table 3.

would probably be excessive for the turboprop application (see Table 6).

Surface Arrangements 2 and 3 yield designs of practical weight, although the volumes are somewhat too great. Arrangements 4, 5, and 6(a) show what can be accomplished with plate-fin surfaces. It should be noted that one surface could be used for the gas side component and another for the air side component. It might be desirable from a fouling point of view, for example, to employ Surface Arrangement 4 in the gas side component and one of the more effective surfaces in the air side component.

Surface Arrangement 6(a) in the design Nos. 11 and 12 combination yields a core weight of 0.168 lb. per s.hp. Adding the liquid, the piping, pump, etc., it appears that a total weight chargeable to the regenerator of the order of 0.30 lb. per s.hp. is possible of attainment. This should be evaluated against the approximate improvement in fuel economy of 0.10 lb. per s.hp.-hr., as compared to the simple turboprop ($P^* = 6$), see Fig. 4.

Design Nos. 13 and 14 employ Surface Arrangement 6(a) with $NTU_c/NTU_h > 1.00$ in order to approach optimum heat-transfer area distribution, as discussed in connection with Fig. 6. It will be noted that there is a slight reduction in volume and weight but that the optimum is not at all critical. Of possibly greater importance is the fact that this results in a considerable reduction in the size of the hot side component at the expense of the cold side component. This may be quite desirable, since the hot side component may be the critical one with regard to fouling and high temperatures. As has been previously mentioned, reduction in hot side component size is also affected by carrying the larger portion of the per cent pressure drop on the hot side.

Design Nos. 15 and 16, Surface Arrangement 6(b), show the improvement possible if a fin material with the properties of copper can be employed. Although the fin material density is greater than steel used for the previous designs, the high thermal conductivity of copper allows the use of thinner fins and results in a considerable reduction in weight, as well as volume.

Design Nos. 17 and 18, Surface Arrangement 6(c), show what could be accomplished if a fin material with the density and thermal conductivity properties of aluminum could be employed (note that steel is still retained for the plate material). If such a construction were possible, the weight of the coupling liquid, piping, pump system, etc., would exceed the heat-exchanger core weight (0.07 lb. per s.hp.). Although it is doubtful that aluminum fins could be used for the entire system, it is certainly a possible material to use for the cooler parts of the cold side component.

Two additional notions have been incorporated in design Nos. 17 and 18 to illustrate the flexibility of the liquid-coupled system and the options that are open to the designer. In order to reduce the size of the hot side component, the *NTU* ratio is overbalanced in favor of the cold side component ($NTU_c/NTU_h = 3.00$). The heat-transfer effectiveness of the hot side component is 0.56, while that of the cold side component is .800. An examination of the ϵ-*NTU* curves for the mult.-pass cross-counterflow heat-exchanger system, Fig. 5, will indicate that there is little to be gained by multipassing on the hot side, while four liquid passes are definitely worth while on the cold side. This results in a simpler system on the hot side, while the longer airflow length on the cold side allows four liquid passes. It should be noted that the low *NTU* requirement on the hot side results in a short gas-flow length (less than 3 in., see Fig. 8), which should be advantageous for cleaning and maintenance purposes.

A second advantage of overbalancing the *NTU* ratio is evident from an examination of the peak system temperatures given in Table 7. The peak coupling-liquid temperature is reduced from 854° to 772°F. Since the heat-transfer resistance is overwhelmingly on the gas or air side of the regenerator components, the core surface material tends to operate at close to coupling-liquid temperature. The differences between the peak liquid temperatures and the peak fin metal temperatures, as shown in Table 7, are due to the temperature variation in the fins. It is thus seen that the heat-exchanger surface temperatures can be minimized by overbalancing the *NTU* ratio in favor of the cold side component and by the use of high thermal conductivity fin material. The minimum coupling-liquid temperature for the aluminum designs, Nos. 17 and 18, is 476°F. It may be possible to employ a material

such as aluminum for the fins in at least the first two passes on the cold side where the surface temperature would not exceed 600°F.

Calculations for the pumping requirement for circulating the coupling liquid, assuming a liquid comparable in properties to Na-K alloy, indicate that it is moderate, being of the order of 2 hp. per 1,000 s.hp. plant rating, including pumping and piping losses in addition to the heat-exchanger core friction requirement. For a 4,000–5,000 s.hp. plant, the coupling-liquid transfer lines would be of the order of 3–4 in. in diameter.

Comparison with High Pressure Ratio Turboprop

A major question that arises at this point is how does the liquid-coupled regenerator-turboprop compare with the simple turboprop and, more particularly, the high pressure ratio turboprop?

The studies reported in reference 8 indicate the following zero ram, sea-level specific weight comparison:

Pressure ratio 6:1	0.50 lb. per s.hp.
Pressure ratio 14:1	0.622 lb. per s.hp.
Pressure ratio 20:1	0.635 lb. per s.hp.

In contrast, based on the studies reported here, the 6:1 pressure ratio plant with a liquid-coupled regenerator would have a specific weight of 0.70–0.80 lb. per s.hp. This greater weight is compensated for by a 20 per cent improvement in fuel economy, compared with a 6:1 pressure ratio simple turboprop; even for the 14:1 and 20:1 plants there is about a 4–5 per cent improvement (for a turbine inlet temperature of 2,000°R.). Consequently, as concluded in both references 8 and 9, for flight ranges in excess of 3,000 miles and speeds of the order of 300 m.p.h. the regenerator-turboprop plant is competitive with the high pressure ratio simple turboprop. Which development can most readily be consummated is a debatable point that, it is believed, can best be answered by actual experience with both systems.

Conclusions

This study suggests the following important conclusions:

(1) The development of the liquid-coupled indirect-transfer regenerator hinges on the availability of a good coupling fluid. Some of the liquid metals appear to be best suited for this purpose, but much remains to be learned about their handling problems. Reference 5 contains an up-to-date summary of available information on this subject.

(2) Granting that such coupling liquids will be developed, the liquid-coupled indirect-transfer regenerator appears to offer a practical solution to the problem of a regenerator for the aircraft turboprop system. If extended area heat-transfer surfaces are employed, the total weight and volume chargeable to the regenerator are reasonable, relative to the improvement in fuel economy, and, in addition, the small frontal area characteristic of the simple turboprop without regenerator is maintained.

(3) The liquid-coupled regenerator-turboprop appears to be much superior to the simple turboprop at 6:1 pressure ratio and is competitive with the simple turboprop even at its optimum compression ratio (14–20:1 for $T_{\text{turb.}} = 2{,}000°\text{R.}$) for flight ranges greater than 3,000 miles.

(4) The heat-exchanger designer is allowed a degree of flexibility not possible with direct-transfer regenerators. Specifically, the peak temperatures of the heat-exchanger materials may be reduced to a certain extent by shifting area to the cold side component, different parts of the system may be constructed of different materials compatible with the temperatures reached, and the hot and cold side components may be independently shaped to best fit the machinery arrangement. Because of this flexibility, such lightweight materials as aluminum, and possibly titanium, may be used in parts of the system to substantially decrease weight. The short gas-flow lengths in the hot side component (3–4 in.) will simplify inspection, cleaning, and replacement.

(5) The theory for the liquid-coupled indirect-transfer regenerator provides the following operating and design criteria: (a) The coupling-liquid flow rate should be controlled with plant load so as to maintain an approximate unity ratio of C_L/C. Performance drops substantially for C_L/C less than unity but only moderately for C_L/C greater than unity. (b) The heat-transfer area distribution between hot and cold units may be adjusted within the range

$$0.75/(U_c/U_h) < A_c/A_h < 2.0/(U_c/U_h)$$

without appreciable penalty in performance or transfer area requirement.

This study was prepared only to indicate what may be realized from a geometrical point of view with the liquid-coupled indirect-type regenerator using compact surfaces. These designs, as a consequence, are not to be considered as optimum. Moreover, as it may not prove to be practical to fabricate any or all of these surfaces for high-temperature service, these designs may not even be possible of realization. There also remains the major question of the availability of a suitable coupling liquid. Nevertheless, such studies are essential preliminaries to provide an inducement to develop the necessary manufacturing arts and to develop suitable coupling liquids. It may also be speculated that nuclear power-plant heat-exchanger developments may in the near future lead directly to liquid-coupled regenerators suitable for the turboprop.

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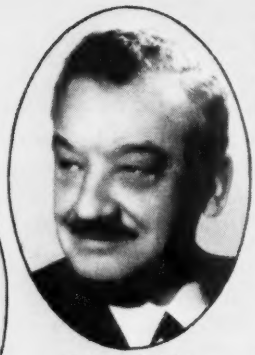
(*Concluded on page 124*)



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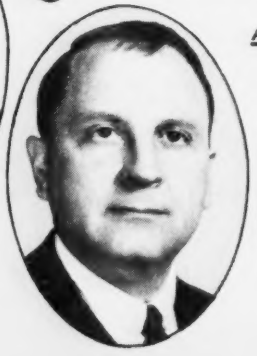

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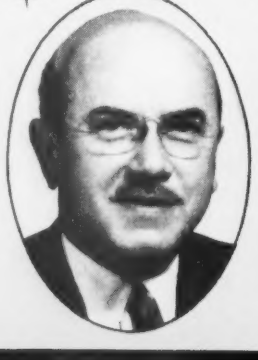

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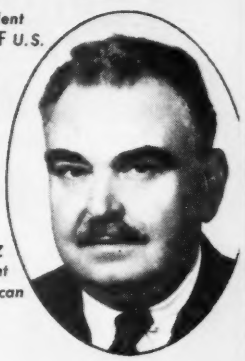

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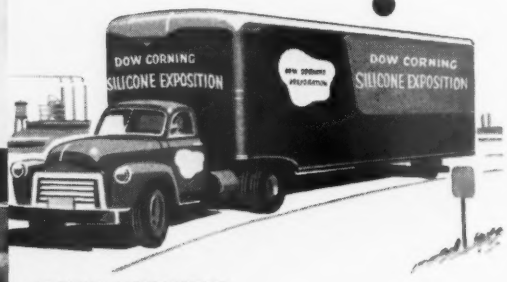

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The Aerodynamic Forces on Low Aspect Ratio Wings Oscillating in an Incompressible Flow

By

H. R. Lawrence and E. H. Gerber

Cornell Aeronautical Laboratory, Inc.

A method for calculating the aerodynamic forces acting on a harmonically oscillating low-aspect-ratio wing in incompressible flow is presented for the class of plan forms with straight trailing edges. The aerodynamic lift and moment resulting from oscillatory vertical translation and rotation are computed for rectangular and triangular wings of aspect ratios ranging from 0 to 4 with reduced frequencies from 0 to 1. The aerodynamic forces arising from the harmonic rotation of 25, 37, and 50 per cent chord trailing-edge flaps are computed for rectangular wings of aspect ratios 1 and 2 for the zero to unity reduced frequency range. The results are shown to be in accord with the Garrick theory for plan forms of very low aspect ratio and with the infinite aspect ratio theory for rectangular wings. In the limiting case of zero frequency, the results reduce to the steady-state solutions of an earlier paper by Lawrence. A rapid method for solving the integral equation is developed for cases where the steady-state solution has been expressed in matrix form.

On the Temperature Distribution Along a Semi-Infinite Sweat-Cooled Plate

By

Nathan Ness

Polytechnic Institute of Brooklyn

A theoretical investigation of the temperature distribution along a semi-infinite porous flat plate under the condition of uniform injection from the bottom of the plate is made.

A heat-balance differential equation of the second order, including a term containing the physical parameters of the plate, is derived and is employed in conjunction with the well-known Prandtl boundary-layer equations of continuity, momentum, and energy for a solution of the problem.

The temperature distribution along the plate is obtained for the respective cases of thermal conductivity not equal to and equal to zero. Results show that the inclusion of the thermal conductivity term in the heat-balance equation eliminates the infinite temperature gradient at the leading edge.

Other results when thermal conductivity is considered are: (a) The boundary conditions at the leading edge—i.e., the ratio of wall to free-stream temperature and the axial temperature gradient there—may not be chosen arbitrarily but are related mathematically to each other; (b) the ratio of thermal to velocity boundary-layer thickness is less than unity at the leading edge for Prandtl Numbers greater than 0.35 and is equal to unity at an infinite distance downstream; (c) at an infinite distance downstream, the wall temperature approaches the coolant temperature.

A Free Flight Investigation of the Possibility of High Reynolds Number Supersonic Laminar Boundary Layers

By

Joseph Sternberg

Ballistic Research Laboratories, Aberdeen Proving Ground

A modified V-2 was fired October 26, 1950, at White Sands Proving Ground to determine whether, under favorable conditions, laminar flow at high Reynolds Numbers at supersonic speeds was possible. The test area was the surface of a special polished 20° included angle conical nose more than 8 ft. long, which replaced the standard V-2 warhead. The rocket reached M = 3 at 25,000 ft. in approximately horizontal flight before it exploded from unknown causes. With the large thermal inertia of the 0.18-in. thick skin, the skin temperature lagged well behind the boundary-layer recovery temperature. Consequently, during most of the supersonic portion of the flight, the heat transfer from the air to the surface was greater than that required to damp small boundary-layer oscillations according to Lees' theory.

Please do not order Preprints of these papers at this time.

Measurements of the nose skin temperature and of total pressures in the boundary layer were telemetered in order to establish the laminar or turbulent state of the boundary layer. The pressure and temperature data indicate that the cone boundary layer was laminar at an equivalent flat plate Reynolds Number of 5×10^7, which was the largest Reynolds Number obtained on the cone.

Creep Collapse of Viscoelastic Columns with Initial Curvatures

By

Harry H. Hilton

University of Illinois

Collapse due to creep of a viscoelastic column is investigated by using the generalized viscoelastic stress-strain relationship. An expression is derived for the ultimate time of the viscoelastic column in terms of its arbitrary initial curvature, the applied load, the material properties, and the ultimate moment of the equivalent elastic column. The results are then applied to two specific viscoelastic bodies—namely, the standard linear solid and the Maxwell body.

On the Application of Statistical Concepts to the Buffeting Problem

By

H. W. Liepmann

California Institute of Technology

This study is intended as a step in the direction of an understanding of the problem of buffeting. The buffeting discussed here is of the type encountered when the wake of some part of the airplane interferes with the tail surface, as happens, for example, during the stall. To approach the general buffeting problem immediately does not seem promising; hence, first, a

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But unfortunately our warning system is not complete. We need 300,000 more volunteer observers! WE MUST HAVE MORE GROUND OBSERVER CORPS MEMBERS TO ASSURE 24-HOUR WATCH OF ALL VULNERABLE U. S. AREAS.

Radar cannot do the whole job, because ground stations can't always spot planes flying under 5,000 feet. The only immediate answer is sheer man power—patriotic men and women who will donate just a few hours each week to the security of the U.S. and themselves.

Too few people realize the need or urgency. *You* can help—by joining the Ground Observer Corps and by spreading the word. To volunteer, simply call your nearest Civilian Defense Office. Or send a postcard to Ground Observer Corps, United States Air Force, Washington 25, D. C.

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ENEMY AIRCRAFT COULD PENETRATE U. S. DEFENSES

Early this summer top U.S. Air Force officials met with Civil Defense directors from 46 states and four territories, and reviewed in confidential detail the current efforts to defend America from surprise enemy attack.

"Despite a $300,000,000 radar fence around the nation's perimeter, gaps exist through which enemy aircraft could penetrate our defenses undetected," the meeting was told.

That's why America needs a total of 500,000 civilian skywatchers as members of the Ground Observer Corps. Nearly 200,000 have already volunteered.

"The only practical means of filling the gaps in our defenses is through a 24-hour operation by civilian volunteers," the meeting was told.

Why isn't America's radar network sufficient?

Defense gaps exists because of radar's line of sight principle, and radar's failure to penetrate opaque masses. Every mountain, every hill casts a shadow behind which enemy aircraft could sneak undetected. Even in perfectly flat country the curvature of the earth shortens the effective range. Equally alarming, radar is susceptible to jamming.

These gaps cannot be filled by Air Force personnel due to the staggering expense. That's why civilians are needed in 27 perimeter states to man Ground Observer Corps stations 24 hours a day. Here is a critical, patriotic job that requires just a few hours a week from each volunteer.

Aircraft too are an important part of our national warning system and of course are the backbone of defense against attack. Three advanced Lockheed planes play a vital role:

The WV-2 *Super Constellation* Early Warning Aircraft, developed for the Navy and the Air Force to extend radar's range in a whole new concept of national defense.

The P2V *Neptune* Navy Patrol Bomber, charged by the Navy with anti-submarine patrol and protection of U. S. coastal waters.

And the F-94C *Starfire*, the nearly automatic all-weather interceptor, which does the final job of climbing to the attack at terrific speed, locating the invaders, and shooting them down with more than human accuracy.

When the U. S. has all necessary planes and personnel—civilian and military—it will be difficult for enemy aircraft to penetrate U.S. defenses.

simpler problem is studied to bring out some general features of the buffeting problem which are believed to be important. The problem studied is the lift force exerted upon a two-dimensional thin airfoil moving in turbulent air. The state of turbulence will later on be restricted to isotropic turbulence, since the characteristics of this type are the best known and simplest. The explicit results gained from the present analysis will not be immediately applicable to tail buffeting, since the model is certainly oversimplified.

The lift exerted upon an airfoil moving in turbulent air is regarded here as the response of a linear system to a random forcing function. The explicit use of the random character of the forces exerted by the turbulent air is believed essential for an understanding and handling of buffeting. This concept obviously extends beyond the applicability of the simple model discussed here in detail. The concepts used in studying the response of a linear system under the action of a random input force are by no means new. For example, the idea of random phases, which leads up to the so-called power spectrum, goes back to Lord Rayleigh. The theory of generalized harmonic analysis has been developed in connection with communication engineering and related problems mostly by Wiener and his school. A parallel and often independent development went on in the theory of turbulence, where the same concepts of correlation functions, power spectrum, etc., have been systematically introduced by G. I. Taylor, Th. von Kármán, and others and used extensively since then. In other branches of aeronautics and aeroelasticity, these concepts and their use are comparatively unknown, and this fact excuses the rather lengthy and detailed discussion of simple concepts in the present paper. The author is well aware of the fact that many of the problems discussed and many of the concepts used are not new. It is the main purpose of the paper to call attention to the use of the statistical concepts in aeronautics and to demonstrate their application with a simple example.

The Subsonic Calculation of Circulatory Spanwise Loadings for Oscillating Airfoils by Lifting-Line Techniques

By

M. A. Dengler and Martin Goland

Midwest Research Institute

A theoretical model is proposed to permit the convenient calculation of subsonic circulatory spanwise loadings on oscillating finite-span airfoils. The basis for the model is a lifting-line construction that represents a fairly direct extension of the Weissinger steady-state model to the os-

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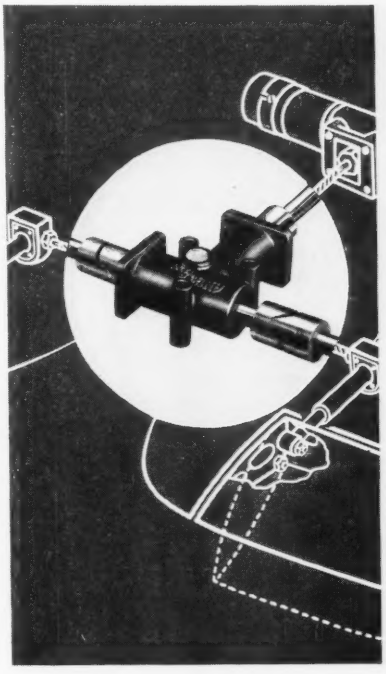

A 3-way ANGLgear® right angle bevel gear unit supplements an R-118 Rotorac® Electric Rotary Actuator in this typical *Airborne-actuated* system. ANGLgear—with the capacity of units many times its size—is ideal for such close-quarter applications. Its compact design, hardened gears, ball bearings, flanged end mountings, 3-bolt side mountings, and an internal pilot on the mounting ends are plus features.

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cillating case. It is shown how the present techniques permit treatment of swept wings with the same convenience normally encountered with straight wings.

To evaluate the performance of the model, a study is made of the spanwise loadings on an upswept rectangular wing of aspect ratio 5, oscillating with reduced frequency $^1/_2$ in six different spanwise-symmetrical modes of motion; the results of calculations are reported on the basis of the present model and on the basis of two prior theoretical treatments. An unswept wing is dealt with in the evaluation, since a theoretical background is available only for this class of oscillating wings. Calculations are also reported for a rectangular wing of aspect ratio 5 and 45° sweepback, undergoing the same types of motions as the unswept wing.

The considerations of this paper lead to certain general observations regarding the character of the Prandtl, Cicala, and Weissinger wing theories. An effort is made to show how the present ideas stand in relation to current literature on the subject.

Finally, recommendations for further study are made, aimed toward development of a practical design-office procedure for the aerodynamic treatment of oscillating wings of general plan form.

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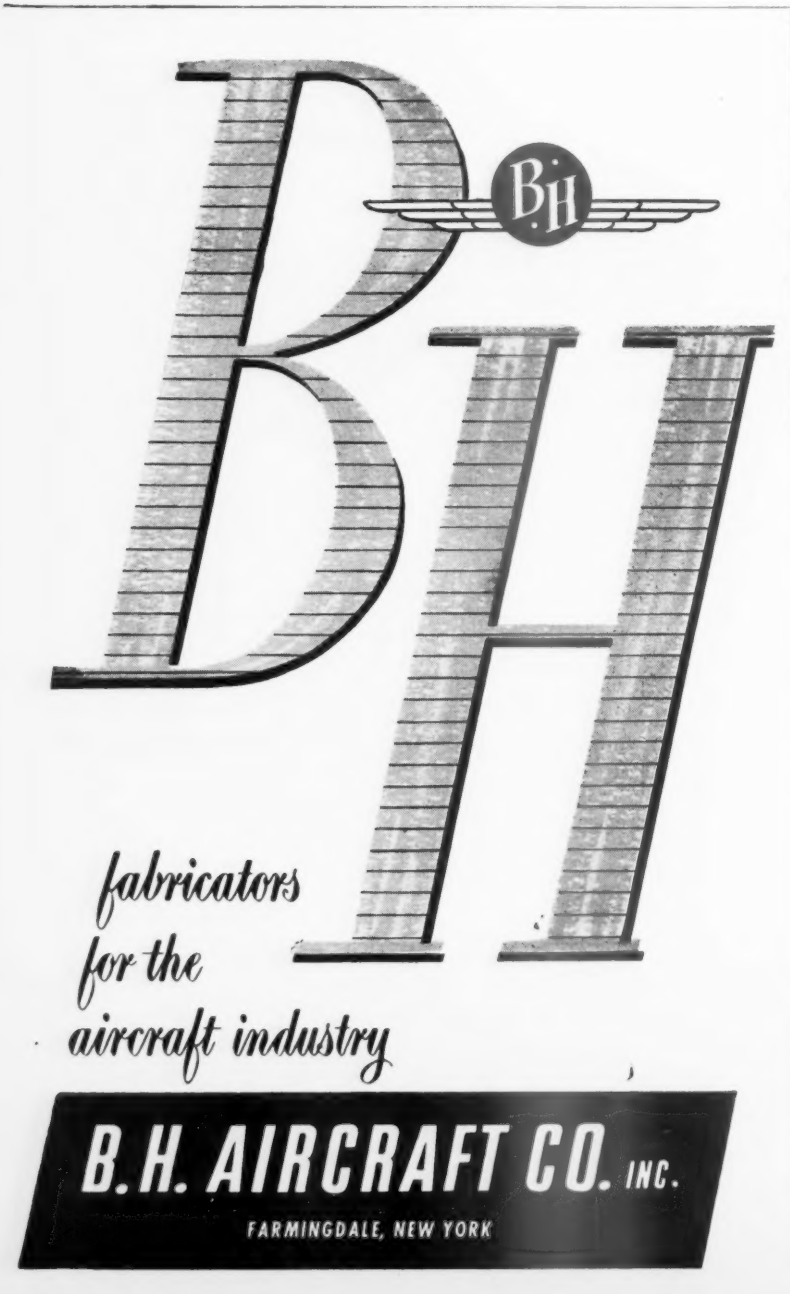

Lateral Instability of Rectangular Beams of Strain-Hardening Material Under Uniform Bending

By

W. H. Wittrick

University of Sydney, Australia

The problem considered in this paper is that of the lateral buckling of initially straight beams of thin deep rectangular cross section under uniform bending, when the bending moment is large enough to cause plastic flow to occur over part of the cross section. The solution applies to any shape of stress-strain curve and represents a generalization of that given by Neal for the case of mild steel bars.

Numerical calculations are made for two different materials, one representative of an aluminum alloy and the other of annealed mild steel, and the two materials are compared.

An Impulse-Momentum Method for Calculated Landing-Gear Impact Conditions in Unsymmetrical Landings

By

Robert T. Yntema

Langley Aeronautical Laboratory, N.A.C.A.

A brief review of the landing process is made, and the importance of the unsymmetrical landing condition is considered. A simple impulse-momentum method that takes account of approach conditions and airplane geometric and inertia characteristics is given for calculating landing-gear contact conditions for successive impacts in unsymmetrical landings. Calculated results for a large airplane are used to compare the severity of landing-gear impacts in unsymmetrical and symmetrical landings and to show the effects of such factors as sinking speed, wing lift, and side drift on impact severity in the unsymmetrical case. The importance of landing-gear location and configuration is also shown by a comparison of the contact conditions for two similar airplanes—one having a conventional tricycle arrangement of gears and the other having a quadricycle arrangement.

Elastic Stability of Simply Supported Flat Rectangular Plates Under Critical Combinations of Longitudinal Bending, Longitudinal Compression, and Lateral Compression

By

Robert G. Noel

North American Aviation, Inc.

A theoretical investigation was made of the buckling of simply supported flat rec-

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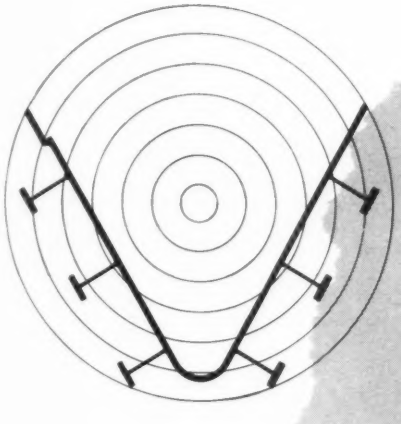

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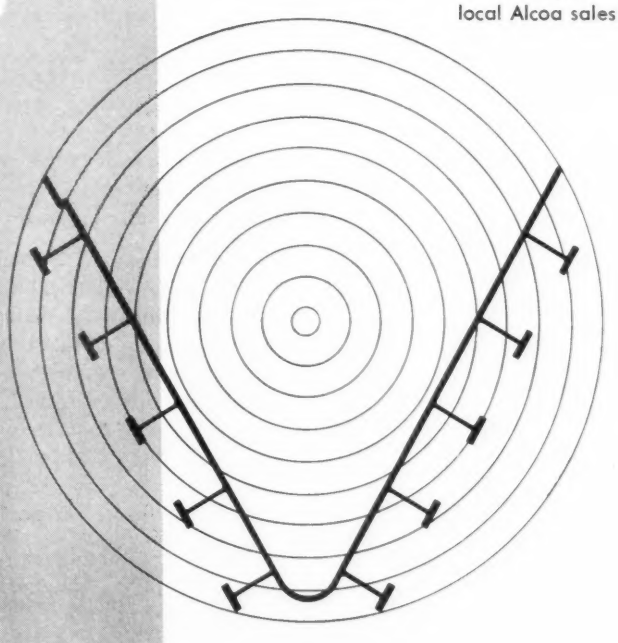

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tangular plates under critical combinations of longitudinal bending, longitudinal compression, and lateral compression. Interaction curves for these loadings are presented for various plate aspect ratios. Also included are curves of critical buckling constants for simply supported flat rectangular plates under combined unsymmetrical bending and lateral compression. The results indicate that the reduction in the allowable bending stress due to the addition of lateral compression is greatly magnified by the further addition of only a small longitudinal compressive load.

On the Flow Behind an Attached Curved Shock

By

S. I. Pai

University of Maryland

The flow field behind a curved shock is investigated. The essential feature of this flow pattern is that the flow is rotational with nonuniformity of entropy. The characteristic differential equation of the stream function for this flow pattern in both the two-dimensional and the axially symmetrical case is derived and then linearized by an extended form of the Ackeret iteration method.

The first-order linearized differential equation of the stream function, the so-called Sears equation, is solved for the flow over a plane ogive behind an attached curved shock. The flow patterns are divided into two groups—one is designated as "weak shock," behind which the flow is still supersonic, and the other is designated as "strong shock," behind which the flow is subsonic. They are investigated separately. Analytic expressions for the flow field for both cases are obtained.

The velocity field can be divided into three components—i.e., one is due to the basic disturbances from the surface of the ogive, the second is due to the reflected disturbances from the shock front, and the third is due to vorticity. Their relative contributions are indicated.

The first-order linearized theory fails at two points: One is that point where the change of stream function due to the change of velocity and that due to the change of density just cancel each other so that the velocity distribution is indeterminate from the stream function. The other point is that at which the reflecting disturbance, itself, satisfies the Rankine-Hugoniot relations; then, according to the first-order linearized theory, the boundary condition at the shock front cannot be satisfied. Both of these points occur in the weak shock region. Excluding the immediate neighborhood of these points, the first-order linearized theory shows the general behavior of the flow pattern behind the curved shock. Within the neighborhood of these two singular points, it is suggested that the exact differential equation should be used which can be solved by the method of characteristics because the flow behind the attached shock is still supersonic.

The Shock Ignition Engine

(*Concluded from page 27*)

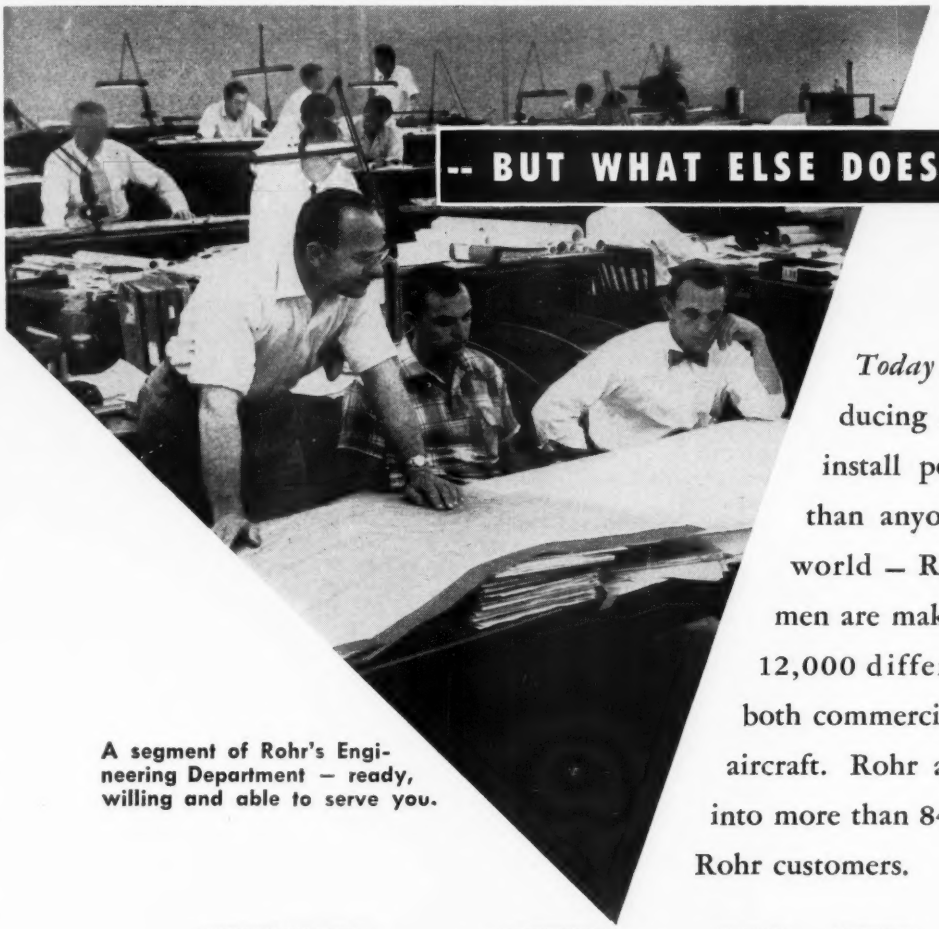
The new engine would be self-starting. Before the fuel was injected, the normal shock would be downstream of the design point. Once the fuel was ignited through the action of the shock wave, a new controlled position would be established. As mentioned above, the effective back pressure would stabilize the shock wave at the design point in the divergent portion of the inlet diffuser.

There are many disadvantages to such an engine. The normal shock in the divergent portion of the inlet diffuser would be somewhat more intense than present stability conditions would require. This total pressure loss due to increased intensity of shock would be somewhat compensated for by the fact that no loss would be developed at the flameholders. Another disadvantage to this form of engine is the lack of data. There has not been enough basic work done to determine the correct fuel or fuel-air mixture that could be employed with various gases. In addition, the effect of pressure and temperature on the various fuels and fuel-air mixtures should be determined. More work of a basic nature should be done with liquid fuels such as are normally employed today in the various jet engines. In addition to this, more work with air under conditions similar to those expected in the upper air should be undertaken. Another big disadvantage is the lack of data for spraying and mixing of fuels at supersonic velocities. The inlet diffuser might have to be lengthened considerably in order to establish a fairly homogeneous fuel-air mixture upstream of the ignition wave.

The shock tube and the bullet experiments outlined above are rather economical ways to carry out this type of research. One of the main reasons for writing this paper is to interest people in this method of initiating and maintaining continuous combustion. If more people were actively engaged in such a program, this form of ignition could perhaps be utilized in the near future.

Summarizing Remarks

This form of ignition presents a somewhat different plateau for activation and combination of molecules for the liberation of heat. The engine proposed in this paper is not necessarily the final form that this type of engine would have. It is, however, an indication of the type of engine that is possible. In addition to the steady flow cycle outlined above, perhaps some form of shock ignition could be employed in an unsteady flow cycle. It has been demonstrated that shock waves can be made to collide resulting in tremendous temperatures. Perhaps this technique could be employed in some unsteady flow cycle to give an efficient engine for lower supersonic flight Mach Numbers.



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I.A.S. News (Continued from page 18)

will be made available for the laboratory project.

The Aeronautical Structures Laboratory will be opened to students who hold B.S. degrees in aeronautical or civil engineering, provided their undergraduate records indicate an aptitude for graduate work. Trainees will point toward structural analysis or design for the aircraft industry or toward research in those fields. Graduate degrees of M.S., Ph.D., and D.Eng. will be offered, with opportunities for continuing into the postdoctoral study.

New Corporate Member

Anderson, Greenwood & Company, of Houston, Tex., an aircraft company established in 1946, recently joined the Institute of the Aeronautical Sciences as a Corporate Member.

For well over a year, this group has been handling for Consolidated Vultee Aircraft Corporation, San Diego, complete air-frame-design responsibility on major components of the Navy's R3Y turboprop flying boat. This work includes working drawings, stress analysis, weight control, etc. Only recently, the company started highly classified design studies for Boeing Airplane Company, Seattle, in addition to other studies and design projects for Boeing's Wichita Division.

On its own behalf, Anderson, Greenwood also has under development design of military aircraft and related items. The company says that it is able to do this because of the excellent background experience acquired by its officers during the many years that they were with Boeing's Engineering Division in Seattle. The company further says that it is capable in air-frame design, high-speed aerodynamics, missile design, etc.

Prior to undertaking its military program, Anderson, Greenwood & Company designed, certificated, and produced the AG-14 pusher-type all-metal aircraft completed in 1950.

The company has outgrown its present quarters. Consequently, it is moving to new facilities being erected on a 16-acre tract. The new location will, it is believed, permit ample room for expansion.

News of Members

▸ **V. Cadambe** (M.), Assistant Director and Head of Division of Applied Mechanics and Materials, National Physical Laboratory of India, New Delhi, India, was named a Delegate by the government of India's Ministry of Natural Resources and Scientific Research to participate in the Eighth International Conference on Theoretical and Applied Mechanics held at Istanbul from August 20 to 28, 1952.

▸ **William Scott Farren** (F.), Technical Director, A. V. Roe & Company, Ltd., England, was recently elected a Vice-President of the Royal Aeronautical Society.

▸ **Peter Gordon Masefield** (A.F.), Chief Executive and Member of the Board, British European Airways, England, was recently elected a Vice-President of the Royal Aeronautical Society.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of I.A.S. members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

Andrew E. Abramson (T.M.), Research and Engineering Division, Washington Machine and Tool Works, Inc. Formerly, Aeronautical Research Scientist, Lewis Flight Propulsion Laboratory, N.A.C.A.

Major Walter D. Bennett, U.S.A.F. (T.M.), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Formerly, assigned as Air Force Trainee in Industry, Guided Missile Project, Boeing Airplane Company.

Second Lieutenant George L. Bergst, U.S.M.C.R. (T.M.), Engineering Officer, VMA-251, MAG-15, U.S. Marine Corps Air Station, El Toro, Calif. Formerly, 12 SBC, 2nd Trn. Batt., Marine Corps Schools, Quantico, Va.

Joseph A. Bligh (T.M.), Model Design, Northrop Aircraft, Inc. Formerly, Junior Engineer "B," B-52 Liaison Group, Boeing Airplane Company.

Captain James L. Bode, U.S.M.C. (T.M.), Hedron 2—Operations, 2nd M.A.W., M.C.A.S., Cherry Point, N.C. Formerly, Pilot, Delta Air Lines.

David D. Bowe (M.), Assistant General Sales Manager, Aeroproducts-Allison Division, General Motors Corporation. Formerly, Chief, Aerodynamics and Application Unit, Engineering Department, Aeroproducts-Allison.

Private Harold Bryman, U.S.A. (T.M.), now Co. D, 86th Inf. Regt., 10th Inf. Div., Fort Riley, Kan.

Major Donald D. Carlson, U.S.A.F. (T.M.), Headquarters, Wright Air Development Command, Wright-Patterson Air Force Base, Ohio. Formerly, Captain, Graduate Student, Princeton University.

Andrew F. Charwat (T.M.), Aerodynamicist, Propulsion Research Corporation. Formerly, Instructor, University of California.

William H. Dammer (T.M.), Field Service Engineer for Boeing Airplane Company, assigned now to Lowry Air Force Base, Colo., and formerly to the Boeing plant in Seattle, Wash.

Major William S. Dawson, U.S.A.F. (A.M.), Student Officer, Communications-Electronics Staff Officers Course, Air Command and Staff School, Air University, Maxwell Air Force Base, Ala. Formerly, Director of Plans and Requirements, Headquarters 1808th Airways and Air Communications Service Wing, Military Air Transport Service, Japan.

Major Fred H. Dietrich, U.S.A.F. (M.), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. Formerly, assigned as Air Force Trainee in Industry, Guided Missile Project, Boeing Airplane Company.

R. C. Drinkwater (T.M.), Aeronautical Engineer/Commercial Pilot, Spartan Air Services Limited, Canada. Formerly, Aircraft Design Engineer, A. V. Roe Canada, Ltd.

Douglas Eastman (T.M.), Product Designer (Aircraft), Kaiser Metal Products Co. Formerly, Designer "B," Boeing Airplane Company.

Frank H. Erdman (T.M.), Assistant to the President, McDonnell Aircraft Corporation. Formerly, Assistant Representative in the Washington, D.C., Office, McDonnell.

Thomas W. Fehr (T.M.), Development Engineer, Basic Processes and Engineering Department, Solid Engine Division, Aerojet Division, The General Tire & Rubber Company. Formerly, Engineering Assistant, University of Illinois.

Lewis Filler (T.M.), Instructor, Department of Aeronautical Engineering, New York University. Formerly, Aerodynamicist, Grumman Aircraft Engineering Corporation.

A. P. Fontaine (A.F.), Executive Vice-President, Consolidated Vultee Aircraft Corporation. Formerly, Vice-President and General Manager, Convair.

Charles G. Garrett, Jr. (T.M.), Naval Air Test Center, Patuxent River, Md. Formerly, Test Engineer, McDonnell Aircraft Corporation.

Lieutenant Colonel Bantley H. Harris, Jr., U.S.A.F. (T.M.), Senior Pilot, Air Force Flight Test Center, Edwards Air Force Base, Calif. Formerly, Student Officer (Graduate), Guggenheim School of Aeronautics, College of Engineering, New York University.

William A. Konersman (T.M.), Design Engineer, Goodyear Aircraft Corporation. Formerly, Research Associate, Aeronautical Research Center, University of Michigan.

Gustav Kuerti (M.), Department of Mechanical Engineering, Case Institute

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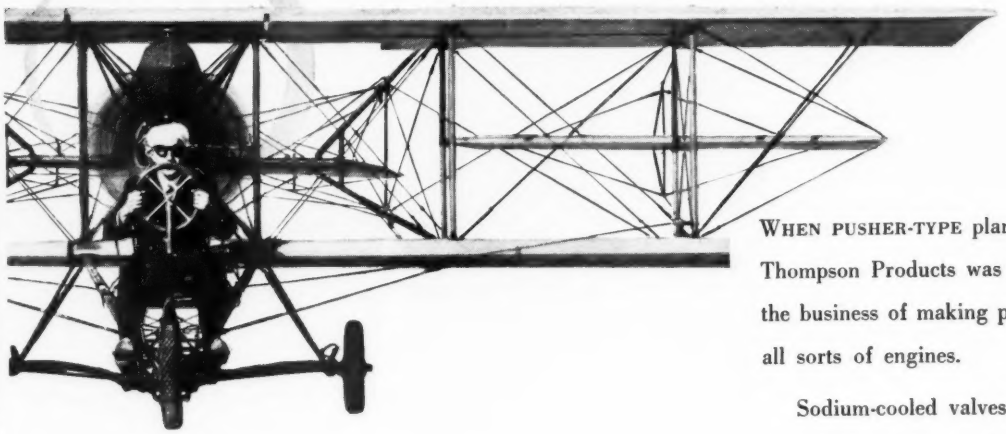

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American Helicopter Society News

Executive Secretary Appointed

Harry M. Lounsbury, of Riverside, Conn., a former Air Force engineering officer and employee of Vought-Sikorsky, has been appointed Executive Secretary of the American Helicopter Society.

He is making his home office at the Institute of the Aeronautical Sciences building, 2 East 64th Street, New York 21, N.Y. However, about one-third of his time is to be spent on field trips according to Thomas R. Pierpoint, A.H.S. President.

Lounsbury, who is 34 years old, has been with Eastern Air Lines since 1946. Starting as a reservations agent, he later became a traffic and sales representative in New York, promoting air travel accounts and taking part in the company's promotional activity in the Wall Street area.

Born in Danbury, Conn., Lounsbury was educated at the Wooster Preparatory School in that city and in 1940 was graduated from the Stewart Technical School of Aeronautics in New York. He was issued C.A.A. Aircraft and Aircraft Engine Master Mechanic's Licenses.

He was first employed in the final assembly department of the Vought-Sikorsky plant in 1940, working on OS2U-1, SB2U-1, and XPBS projects. Prior to test flights, he spent some time working on the VS-300 Sikorsky helicopter.

The day after Pearl Harbor, Lounsbury enlisted in the A.A.F. as an Aviation Cadet, but later he was assigned to engineering. He attended the Air Force O.C.S. in Florida and was commissioned in October of 1942.

During the next 4 years, he served in the Pacific as an Engineering Officer with squadrons flying B-24, B-25, and A-20 aircraft. He left the service as a Captain.

For a short time after the war, he was employed as Curator of the Museum of the Institute of the Aeronautical Sciences.

Lounsbury is married and has two children.

In his new assignment for A.H.S., he is charged with keeping affairs of the home office in order, building up the society's membership, maintaining close liaison with regional activities, and compiling the necessary society history. He is also to lend active assistance to the regional vice-presidents in carrying out their local programs.

"This appointment," A.H.S. President T. R. Pierpoint said in his announcement, "gives A.H.S. its first full-time employee. It marks a big step forward in the society's history, giving us a central desk for the dissemination of information and conduct of our affairs."

Harry M. Lounsbury

No Membership Chairman

President Pierpoint has explained to the society's officers that no chairman has been named for the Membership Committee because of the recent appointment of Secretary Lounsbury.

"It has been agreed," Pierpoint said, "that the permanent secretary should serve as the membership chairman and devote the major portion of his efforts, up to the beginning of next year's Forum preparations, to the building up of the Society's membership.

"We are now just short of the 500 mark and I personally feel we should have no difficulty reaching 1,000 before next year's Forum by virtue of your individual programs and the application of a full-time man to the program."

Contributors to American Helicopter Society News are urged to keep in mind that it takes about 6 weeks for copy to get in print. This page needs material on the activity of regional groups and individual members, but it must be in the hands of the publicity chairman not later than the 5th of the month to appear in the issue of the second month following. Address contributions to Claude O. Witze, Piasecki Helicopter Corporation, Morton, Pa.

Four A.H.S. Talks Printed

Major W. P. (Mitch) Mitchell, U.S.M.C. Project Officer of HMX-1 at Quantico, Va., gave a talk on his Korean experiences recently at a meeting of mid-west A.H.S. members.

Arranged by Vice-President Charles R. Wood, Jr., the session was held at the McDonnell Aircraft Corporation plant in St. Louis. Major Mitchell was attached to the first Marine helicopter squadron to operate in Korea.

Copies of his talk have been prepared by McDonnell and will be distributed to members by the New York office.

Another meeting was held by the West Coast unit, where papers were delivered by James Brye, Chief Aerodynamicist of McCulloch Motors, and Fred W. Milam, Operations Manager of Los Angeles Airways. According to Robert A. Wagner, West Coast Vice-President, these papers are being reproduced by McCulloch for distributon to A.H.S. members.

A fourth talk, one delivered by Wieslawz Stepniewski, Director of Aerodynamics at Piasecki Helicopter Corporation, has been reproduced by his company and soon will be distributed. It was delivered this summer before the Canadian Institute of Aeronautical Sciences.

Three Cities Bid for 1953 Forum

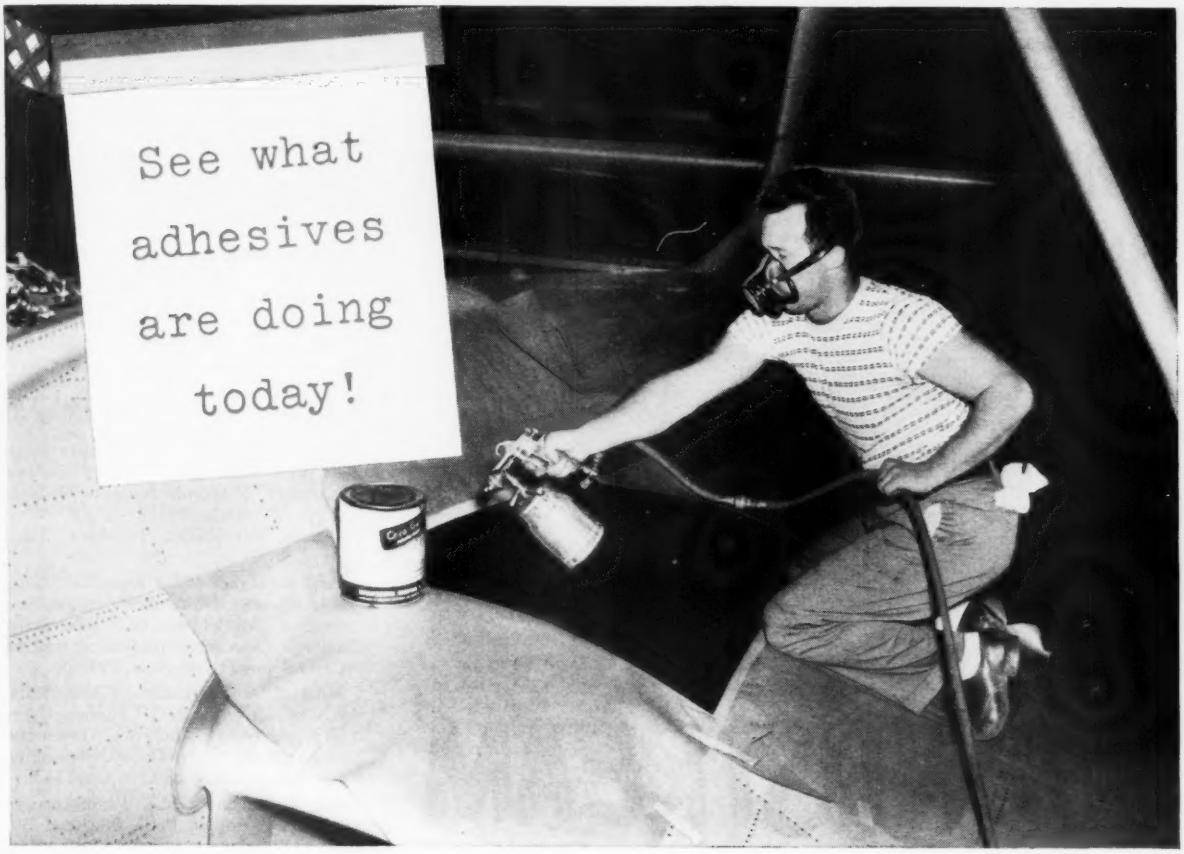
A.H.S. now is a candidate in a popularity contest being conducted by civic groups.

Three major cities, impressed by reports of the last Forum, now want to play host for the society's next meeting.

Boston and two cities in Ohio—Cleveland and Columbus—have asked to be considered for 1953.

The decision will be made at the September meeting of the Council, to be held late that month in New York. President Pierpoint has promised that the question will be discussed, but he also has told Cleveland, Columbus, and Boston that A.H.S. is inclined to favor the Washington location, because it is central for the industry and most convenient for military guests.

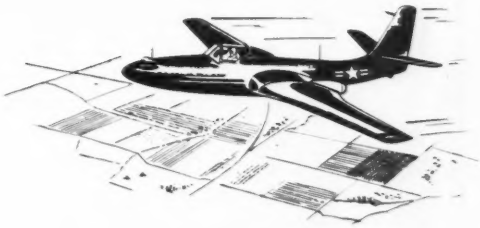
CLAUDE O. WITZE
Publicity Chairman, A.H.S.



Making walkways for Banshees

Making non-skid walkways for airplane wings might not seem like a difficult problem. But keeping any kind of coating on jet-powered wings is next to impossible . . . the windstream tends to peel it off.

The McDonnell Aircraft Company, makers of the Navy Banshee jet fighter, asked 3M for a product that would stay on, yet be flat enough not to set up wind resistance and affect the plane's flight characteristics. 3M engineers suggested this: a primer coat of adhesive and a final coat of Corogard #22, a non-skid coating. The new walkway passed all flight tests, and is now part of the airplane.



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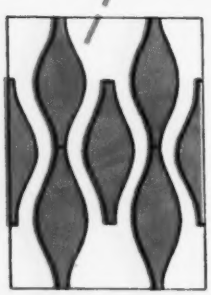

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(*Continued from page 64*)

of Technology. Formerly, Consultant in Applied Mathematics, U.S. Naval Ordnance Laboratory, Silver Spring, Md.

Dr. Peter Kyropoulos (M.), Associate Professor of Mechanical Engineering, California Institute of Technology. Formerly, Assistant Professor of Mechanical Engineering, CalTech.

Dr. Paco Lagerstrom (A.F.), Professor of Aeronautics, California Institute of Technology. Formerly, Associate Professor of Aeronautics, CalTech.

Warner S. Lowe (T.M.), Flight Test Engineer, Consolidated Vultee Aircraft Corporation. Formerly, Graduate Student, Guggenheim School of Aeronautics, College of Engineering, New York University.

Marvin L. Luther (M.), Project Engineer, Wind-Tunnel Section, Jet Propulsion Laboratory, California Institute of Technology. Formerly, Physicist, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.

Emil A. Malick (M.), Assistant Manager, Bluebonnet Plant, Phillips Petroleum Company, McGregor, Tex. Formerly, Technical Consultant and Supervisor of Jet Development Activities, Phillips.

Michael A. Marchese (T.M.), Engineer, Research Group, Grumman Aircraft Engineering Corporation. Formerly, Engineer, Wing Design Group, El Segundo Plant, Douglas Aircraft Company, Inc.

Carl J. Martin (T.M.), Administrative Engineering, Branch 15.05, National Bureau of Standards, Corona, Calif. Formerly, Aeronautical Engineer, Joint Long Range Proving Ground Division, U.S.A.F. Patrick Air Force Base, Fla.

Dr. Philip R. Marvin (M.), now Vice-President, Commonwealth Engineering Company.

Colin Hugh McIntosh (M.), Consultant on Air Transportation, 1417 K St., N.W., Washington 5, D.C. Formerly, Vice-President—Operations, All-American Airways, Inc.

William O. Meckley (M.), Manager of Engineering, Accessory Turbine Organization, Aircraft Gas Turbine Division, General Electric Company. Formerly, Division Engineer, Aircraft Accessory Turbine Products, A.G.T.D., G-E.

Second Lieutenant Eugene D. Moen, U.S.A.F. (T.M.), Pilot Training, Box 693, Spence Field, Moultrie, Ga. Formerly, Work Order Clerk, Post Engineering, U.S. Civil Service, Fort Benning, Ga.

James G. Murray (T.M.), Stress Engineer, Structures Section, Airframe and Equipment Branch, Civil Aeronautics Administration. Formerly, Mechanical Engineer, Naval Research Laboratory.

Lester W. Musser, Jr. (T.M.), now with Goodyear Aircraft Corporation.

Luigi D. Naticone (T.M.), Engineering Draftsman, North American Aviation, Inc. Formerly, Junior Engineer, Testing Detroit Arsenal, Mich.

Arthur W. Niergarth (T.M.), Liaison Engineer, Oliver Corporation. Formerly, Junior Engineer "A," Boeing Airplane Company.

Wilfred Nugent (M.), Commercial Engineering Group, Consolidated Vultee Aircraft Corporation. Formerly, Senior Design Engineer, A. V. Roe Canada, Ltd.

Ensign Seymour Salmirs, U.S.N. (T.-M.), U.S.S. Corregidor (TCVE-58), c/o Fleet Post Office, New York, N.Y. Formerly, Graduate Research Assistant, Daniel Guggenheim School of Aeronautics, Georgia Institute of Technology.

Commander Raymond J. Schneider, U.S.N. (M.), Bureau of Aeronautics Representative, Thompson Products, Inc. Formerly, Development Officer, Aviation Armament Laboratory, Naval Air Development Center, Johnsville, Pa.

Dr. Raymond J. Seeger (A.F.), now Physical Science Administrator, National Science Foundation.

Charles D. West (T.M.), Development Engineer, Missiles Engineering Division, McDonnell Aircraft Corporation. Formerly, Teaching Fellow, Applied Mechanics Department, Virginia Polytechnic Institute.

George William Wilson (M.), Senior Ministry of Supply Official, Directorate of Civil Aircraft Research and Development, St. Giles Court, St. Giles High Street, London W.C.2, England. Formerly, Senior Ministry of Supply Official, British Ministry of Supply at Winter Experimental Establishment, Royal Canadian Air Force, Edmonton, Canada.

Ryan Aeronautical Company: 1922–1952

In September of 1922, T. Claude Ryan (M.) (right) founded Ryan Aeronautical Company, which he still heads and actively manages. Thirty years ago, the assets of this business venture consisted of one war-surplus Jenny, a working capital of $25, and a piano box for a workshop. Today, Mr. Ryan is the President of a multimillion-dollar concern that employs thousands of persons in a 38-acre plant for the purpose of manufacturing aircraft and aircraft parts on a prime- and subcontractual basis.

Corporate Member News

• **Aerojet Division of The General Tire & Rubber Company** . . . A new rocket production facility has been activated on an 8,400-acre site near Sacramento, Calif. This new plant of Aerojet Division (formerly, Aerojet Engineering Corporation) is scheduled to produce ordnance rockets (such as the Aeromite), JATO's, guided missile boosters, and missile power plants. Research, engineering, and metal parts fabrication are remaining at the company's Azusa, Calif., plant.

• **Aeroproducts Division, General Motors Corporation** . . . A Wright R-3350-85 compound engine and an Allison T-40 turboprop engine have been installed in test cells at Aeroproducts for use in checking propellers. The former engine will be used to check props for the Fairchild C-119, series G and H airplanes, while the latter power plant will check props for the Convair R3Y, Douglas A2D, and North American A2J turboprop aircraft.

• **AiResearch Manufacturing Company, Division of The Garrett Corporation** . . . The Engineering Department has been moved into the new 37,500-sq.ft. engineering building at 9225 Aviation Blvd., Los Angeles. This is the first time since 1943 that AiResearch's engineering activities have been housed under one roof.

• **Allis-Chalmers Manufacturing Company** . . . R. S. Stevenson, formerly Vice-President in charge of the Tractor Division, was recently elected Executive Vice-President of the company. Mr. Stevenson was succeeded to his former post by Willis G. Scholl, who had been Vice-President and General Sales Manager of the Tractor Division and who was succeeded in this position by Frank Mussell, Eastern Territory Manager of the Tractor Division.

• **Allison Division, General Motors Corporation** . . . The longest flight attempted to date by an American turbine-powered transport plane was accomplished last July when the Turbo-Liner was delivered to Allison in Indianapolis, Ind., from Edwards A.F.B., Calif. Allison plans to use the Turbo-Liner, which is powered by two 2,750-hp. Allison turboprop engines, in an extended flight test research program. Upon the completion of these tests, it is expected that the ship will be turned over to some of the air lines for cargo service under actual transport operating conditions.

• **Aluminum Company of America** . . . A huge new rolling mill, costing approximately $4,500,000 and capable of producing extra-wide tapered sheet and plate for aircraft, will be installed at Alcoa's Davenport, Iowa, works by late 1953. This equipment will be designed, installed, and operated by Alcoa under terms of a lease arrangement with the U.S.A.F. Air Materiel Command, who will have first call upon the production of the new mill. The mill, capable of rolling widths up to 10 ft. through four-high stands or rolls, will be able to handle hot or cold ingots and will be reversible.

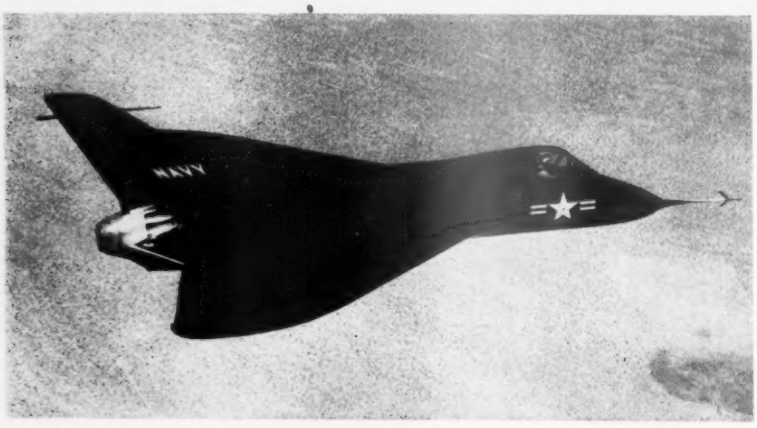
• **American Airlines, Inc.** . . . The Medical Division has established a residency for civilian physicians and flight surgeons who wish to specialize in aviation medicine. A doctor qualifying will be given a year's course in all phases of aviation medicine. The resident will be based at American's Medical Division headquarters at LaGuardia Field, New York.

• **Beech Aircraft Corporation** . . . Sales and production activities for the military services of the United States and allied countries include versions of four different Beechcraft models.

• **Boeing Airplane Company** . . . A KC-97E Stratofreighter, powered by Pratt & Whitney Wasp Major R-4360-59 engines, successfully completed its tests at a gross weight of 175,000 lbs. Normal gross weight of the KC-97E is approximately 150,000 lbs.

• **The Bristol Aeroplane Company of Canada, Ltd.** . . . The sectional Bristol Proteus turboprop engine, recently exhibited during the Society of Automotive Engineers' show at New York International (Idlewild) Airport, New York, is being shown by Bristol throughout the United States and Canada.

• **Cessna Aircraft Company** . . . Shoulder harness fittings are being offered as a standard provision in the Cessna 170 for the



THE XF4D-1 POSES FOR ITS FIRST AIR PHOTO

The XF4D-1 Skyray, shown in its first air picture, was designed and developed by Douglas Aircraft Company, Inc., as a carrier-based aircraft. This high-speed Navy fighter, now undergoing flight testing, is scheduled for production at the Douglas El Segundo Plant.

pilot and passengers. The shoulder harness in question is said to be capable of withstanding 20 g's.

• **Consolidated Vultee Aircraft Corporation** . . . A. P. Fontaine, A.F.I.A.S., who has been serving as Vice-President and General Manager of Convair, has been elected Executive Vice-President of the corporation.

• **Curtiss-Wright Corporation** . . . Paul V. Shields has resigned from his position as a Director of the corporation.

• **Douglas Aircraft Company, Inc.** . . . A new jet-aircraft escape cockpit capsule, which is sealed and pressurized to protect the jet pilot against atmospheric conditions prevailing above 50,000 ft., was designed at the Douglas El Segundo Plant for the Navy's Bureau of Aeronautics. Expelled by the pilot from the aircraft by means of a rocket charge whenever escape becomes mandatory, the capsule is equipped with three aft fins that unfold to stabilize it. A small pilot chute and a large main chute are furnished to slow down the capsule and to lower it gently to the earth's surface. It floats upright on water with wave motions pumping fresh air into the sealed and insulated compartment. Survival gear is included in the escape capsule. . . . What Douglas terms "a new universal bomb shape" was announced on July 14. Designated the Aero X-1A external store, it was designed for the Navy's Bureau of Aeronautics for external use on many modern combat planes and will, Douglas officials state, permit flight at 50 m.p.h. faster than when the World War II type bomb is used. Contoured to produce the lowest drag possible when installed on transonic or supersonic aircraft, the new armament container is said to be standardized for universality of application as a single aerodynamics shape adaptable to airplanes now in service and those anticipated for many years. The shape of this new external store is like that employed by the external fuel tanks now undergoing flight tests for the Navy's F3D Skynight night fighter. . . . The Long Beach Division will engineer and build the twin-jet swept-wing RB-66 jet reconnaissance bomber for the Air Force. The RB-66, the U.S. A.F. version of the Navy A3D, carries a three-man crew and is rated in the 600–700 m.p.h. class. . . . The European headquarters has been moved from Brussels, Belgium, to Geneva, Switzerland.

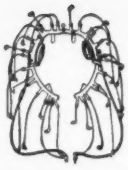
• **Elastic Stop Nut Corporation of America and Tinnerman Products, Inc.** . . . A brochure entitled "Locknuts" was recently put out by the Locknut Section of Industrial Fasteners Institute. In it is given a description and principle of operation of representative types of locknuts. Among the sponsors of this publication are Esna and Tinnerman.

• **General Electric Company** . . . An accessory turbine organization—it has no official name as yet—was recently formed as a new section at the Lynn River Works of G-E's Aircraft Gas Turbine Division. This new operation is responsible for the design, manufacture, and sale of turbine-driven accessories for jet engines and aircraft. Its manager is John P. Turner, Jr. W. O. Meckley, M.I.A.S., was appointed Manager of Engineering, and H. M. Wales was named Manager of Sales. . . . A G-E dewpoint recorder has been installed in N.A.C.A.'s 4- by 4-ft. supersonic wind tunnel at the Langley Aeronautical Laboratory, Va. This is one of the first reported applications of this device in a supersonic wind tunnel. . . . William Rogers Herod has been elected a G-E Vice-President. Mr. Herod will continue as President of International General Electric Company, Inc., although as of last July 31, International G-E ceased functioning as a wholly owned affiliate of General Electric Company and became one of its divisions. International G-E, however, is retaining that name and will continue to have the same responsibility for the conduct of the company's foreign business. Mr. Herod and the other officers of International G-E will retain their titles and continue in the same capacities.

• **Globe Corporation, Aircraft Division and Summers Gyroscope Company** . . . Scheduled to go into production this fall is Globe's newly developed target aircraft, KD6G-2. The KD6G-2 is powered by an inverted 4-cylinder engine especially designed for this drone aircraft and manufactured by Kierkhofer Aeromarine Motors. It is said to be the highest speed target drone yet developed. Control systems and components for the KD6G-2 are being manufactured by Summers.

PROBE-DROGUE REFUELING

Flight Refueling, Inc., has proposed a refueling method, using the probe-drogue system, by which more than one aircraft can be refueled simultaneously from a single tanker aircraft. As indicated in the accompanying artist's drawing, Flight Refueling's method calls for the installation at the tanker's wing tips of relatively lightweight hose reels; the entire refueling operation can be handled remotely by the tanker crew. A forerunner of this system, developed by Flight Refueling, was used to refuel the U.S.A.F.'s Boeing B-50 bomber, "Lucky Lady," which accomplished the first nonstop round-the-world flight in March, 1949.



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Electrical, mechanical, and hydraulic actuators for aircraft controls, valve closures, landing gear, or virtually any other type of equipment to manufacturer's specifications.

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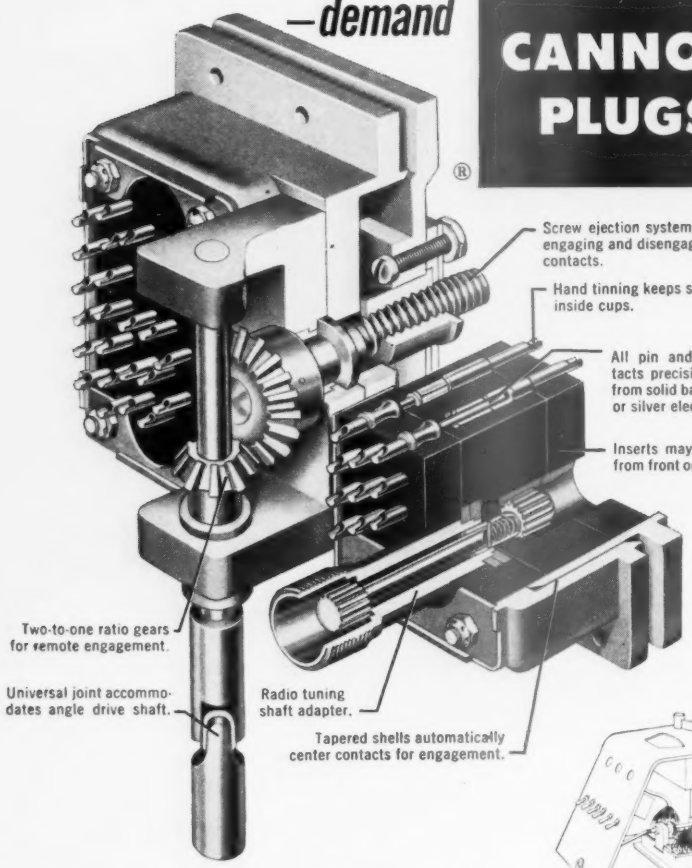
Screw ejection system for engaging and disengaging contacts.
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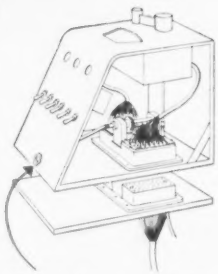
All pin and socket contacts precision machined from solid bar stock, gold or silver electroplated.
Inserts may be removed from front or rear of shell.
Two-to-one ratio gears for remote engagement.
Universal joint accommodates angle drive shaft.
Radio tuning shaft adapter.
Tapered shells automatically center contacts for engagement.

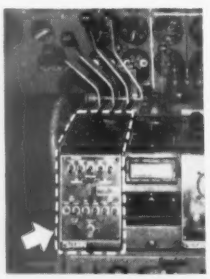
This highly specialized DPD2 Cannon Plug, a member of the DP Series, has its principal use in aircraft instrument panels and remote radio control equipment. But, like many other Cannon Plugs, it has found its way into other fields where the highest quality is needed and where the value of long, trouble-free performance is recognized.

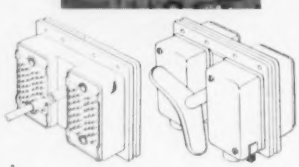
Originally this 2-gang connector was designed to assist in the standardization of radio and instrument assemblies so that such equipment might be interchanged between similar aircraft. It allows for compact design in close quarters with access from the front only. This type of application and variations of the fittings are shown at right. Any Cannon DPD insert may be placed within the shell, with or without tuning shaft, coax, twinax, large or small contacts, provided the separation forces of both halves are similar.

This plug typifies the close attention to important detail that distinguishes every Cannon Plug—the world's most extensive line. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.



Connector is separated by turning slotted shaft here. Complete unit may then be removed from pedestal, shown below.





(Left) Same Cannon Plug without tuning shaft. Straight drive instead of 90° gear. (Right) Similar DPD2 with Dzus wing nut extraction method and junction shells. There are several other variations. Write for details.

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• **Industrial Sound Control, Inc.** . . . Twenty-five thousand pounds of "Soundmetal" panels were ordered by Kaiser Manufacturing Company on a Thursday. This sound-proofing material was fabricated by I.S.C. over the week-end, flown to Kaiser the following Monday, and completely installed in an aircraft-engine test cell by the next Thursday evening. The treated cell was taken over by the U.S.A.F. on the subsequent Monday, 11 days after the initial placing of the order.

• **Jack and Heintz, Inc.** . . . A 16-kva alternator for use in guided-missile aircraft has been developed. This 400-cycle 12,000-r.p.m. unit is cooled by water injection; the cooling water passes through the alternator's hollow shaft and is sprayed through four openings against the internal surfaces of the unit. The steam arising from the resultant water evaporation is emitted through a port. Three and one-half pounds of water are required per hour.

• **Lear, Inc.** . . . The new Learpilot includes a monitoring device that automatically cuts off the autopilot—and warns the human pilot by various signals—whenever a malfunctioning occurs that would normally result in a violent maneuver of the aircraft.

• **Lockheed Aircraft Corporation** . . . A new concrete-reinforced fuselage is now being used as a test jig for research in new types of jet airplane canopies. (Lightweight vermiculite offered a simple and economical method of strengthening the standard fuselage to withstand overload tests.) The new canopies are being pressurized up to three times greater than normal. The first transparent plastic cockpit covers being tested in the concrete rig are designed for the F-94C Starfire interceptors. Other models of new Lockheed-developed canopy designs are also scheduled to undergo complete series of tests during the latter half of 1952 . . . A new series of deliveries of P2V-5 Neptune antisubmarine bombers to Great Britain and Australia was announced last July. . . . Burt C. Monesmith, who has been Manufacturing Manager at Lockheed's California division since 1950, has been elected a Vice-President of the corporation. His new title is Vice-President and Manufacturing Manager.

• **The Glenn L. Martin Company** . . . A flexible gunnery trainer, designated the T-13, has been developed by Martin electromechanical engineers for the Air Force in connection with its strategic bomber program. . . . George B. Shaw and Daniel W. Siemon have been elected Vice-President—Procurement and Vice-President—Industrial Relations, respectively.

• **McDonnell Aircraft Corporation** . . . Several major changes in the executive organization include the establishment of a Contracts Division, a Sales and Service Division, and a Personnel and Public Relations Division. Vice-President Robert H. Charles is in charge of the Contracts Division; John Aldridge, formerly Manager of Customer Contracts, is in charge of Sales and Service; and William R. Orthwein, Jr., formerly Manager of Personnel, is in charge of Personnel and Public Relations. In addition to the

above, several changes were made in the channels through which specified offices report to higher executive levels, and minor alterations were carried out within major divisions to fit the new organizational pattern.

• **Minneapolis-Honeywell Regulator Company** . . . A new jet-engine laboratory, equipped with a network of highly complex electronic computers, controllers, and relays, has been established by the company's Aeronautical Division to accelerate development work on jet-engine controls. The new laboratory, housed in a separate building, has a capacity of 50,000 lbs. of fuel flow an hour. . . . The automatic pilot for helicopters, recently perfected by the company's Aeronautical Division in cooperation with the U.S.A.F. and Piasecki Helicopter Corporation, is now in production and is earmarked by the Air Force for use in the Piasecki H-21 Work-Horse. . . . A series of aircraft fuel gage conferences has been inaugurated by Minneapolis-Honeywell in cooperation with a number of major airplane manufacturers. The first such conference was held last summer at Minneapolis-Honeywell's Aeronautical Division. . . . James H. Binger, who has been Vice-President and General Manager of the company's Belfield Valve Division, was elected a Vice-President of Minneapolis-Honeywell.

• **North American Aviation, Inc.** . . . The F-86H will go into production late this year at the Columbus Division. Only the first two models of the "H" will be produced at the company's Los Angeles plant. Armament will include 0.50 cal. machine guns; the ship will also have an improved suspension and release mechanism for carrying wing tanks in conjunction with bombs or rockets.

• **Northrop Aircraft, Inc.** . . . Northrop Aeronautical Institute has been granted a contract by the Ordnance Corps of the U.S. Army to provide technical assistance in the establishing of a training school for guided missile personnel at Redstone Arsenal, Huntsville, Ala. At this training base, selected Army officers and enlisted personnel will be trained in the fundamentals, principles, procedures, and techniques applied in the operation, repair, and maintenance of guided missiles. This is the first school of this type to be established by the Ordnance Corps under the Ordnance Training Command, with headquarters at Aberdeen Proving Ground, Md.

• **Phillips Petroleum Company** . . . The U.S. Air Force has designated Phillips to operate the Bluebonnet Plant at McGregor, Tex. The plant will produce aircraft JATO units that consume solid fuel and have no moving parts. Personnel to start the preliminary engineering work was moved to McGregor last summer. E. F. Kindsvater is the manager of the new project, and Emil A. Malick, M.I.A.S., is his assistant. . . . A Rocket Fuels Division has been created at Phillips.

• **Republic Aviation Corporation** . . . D. K. Tasker, who for the last 3 years has managed the company's experimental and test-flight activities at Edwards Air Force Base, Calif., was appointed Executive As-

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INDIANA GEAR

The driven gear shown here is 5" in pitch diameter and 15" long overall. It is carburized and hardened with heat-treating distortion held within .001".

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sistant to Tom Murphy, Vice-President and Assistant General Manager of Republic.

• **Seaboard & Western Airlines, Inc., and Curtiss-Wright Corporation** . . . Seaboard & Western's new air-freight fleet of five Lockheed 1049B Super Constellations, powered by Wright Turbo Compound engines, will be equipped with Curtiss Electric Propellers. Delivery is scheduled from Lockheed early in 1954.

• **Solar Aircraft Company** . . . Rear Admiral Wilder D. Baker, U.S.N. (Ret.), has become Consultant to the President of Solar.

• **Sperry Gyroscope Company, Division of The Sperry Corporation** . . . The contract recently announced between the Air Navigation Development Board and Sperry Gyroscope calls for a 2-year flight research program aimed at improving flight safety during instrument-weather approaches to the nation's air terminals. The program was initiated last July. In order to study weather measurement techniques and their relation to flight operation under actual visibility conditions, Sperry flight research pilots, engineers, and technicians will fly 1,000 test approaches through low ceilings at MacArthur Field, L.I., N.Y. Engineering and technical assistance has been provided by the U.S. Weather Bureau, and meteorological instruments developed by the Weather Bureau and the National Bureau of Standards are being utilized. Specifically, this A.N.D.B.-sponsored study will evaluate various methods of measuring and reporting weather conditions from the approach zone on the ground. Simultaneous observations made from the test aircraft in flight will be synchronized with those on the ground. Data so collected should show whether approach-zone weather conditions can be observed and reported to the pilots of incoming aircraft with sufficient accuracy so that the pilot really knows in advance at what altitude he will make visual contact.

• **Thompson Products, Inc.** . . . Present plans of the U.S. Navy call for the construction of a jet-engine test laboratory at Painesville, Ohio, and for its operation by Thompson Products.

• **Trans World Airlines, Inc.** . . . Ten Super Constellations are being put into coast-to-coast service some time this fall. This will augment the line's existing fleet of 68 Constellations. . . . John L. Weller, who has been an Assistant Vice-President of T.W.A. since April, 1951, was elected a Vice-President of the corporation. . . . Brigadier General Nelson S. Talbott, Director of T.W.A. since December, 1936, died suddenly at his home in Dayton, Ohio, on July 6, 1952.

• **United Air Lines, Inc.** . . . Plans have been announced whereby the engines and propellers on United's Douglas DC-6's and DC-6B's and Convair 340's will be standardized within the next 2 years at the cost of $2,000,000. Pratt & Whitney DC-16 engines will be used, as well as Hamilton Standard square-tipped high-activity propellers. . . . Rexford E. Bruno, who was Assistant to United's Vice-President—Finance and Property, has been elected Comp-

troller of the company. Mr. Bruno succeeds Carroll E. Blanchar to this position.

• **Westinghouse Electric Corporation** . . . The existing contract between the Atomic Energy Commission and Westinghouse has been modified to include developmental work on a nuclear power plant suitable for propulsion of large naval vessels such as aircraft carriers. The work will be centered at the Bettis Plant, near Pittsburgh, Pa., operated by the Westinghouse Atomic Power Division. Westinghouse is already under the terms of the A.E.C.-Westinghouse contract, building the atomic power plant and all associated propulsion equipment for the Navy's first atomic submarine, U.S.S. "Nautilus."

I.A.S. Sections

Baltimore Section

J. F. Maloney, *Secretary*

As has become the custom, the annual spring meeting, this year on June 3, was preceded by cocktails on the terrace of the Aeronautical Building at The Johns Hopkins University. A gratifying number of wives and guests was present at the dinner served in Levering Hall at 7:30 p.m.

The meeting was called to order by Chairman Fred Jewett after the dinner. At the speakers' table were: G. Bunker and J. Sweetser, of The Glenn L. Martin Company; A. J. Kullas, the newly elected Chairman; Mr. and Mrs. Ralph Draut; and Rear Adm. Calvin M. Bolster, Deputy and Assistant Chief of Naval Research. Admiral Bolster was introduced by Mr. Draut, Program Committee Chairman, and spoke on "Current Aspects of Naval Research."

The speaker related experiences in early attempts to attach and detach airplanes to rigid airships and to land and take-off from carriers. Methods of catapulting airplanes from ships have been considerably improved from the time in 1940 when only five catapult take-offs were made during that year. Catapults involve first supplying tremendous amounts of energy in a short time and space and then decelerating rapidly. In 1940, 1,000,000 ft.lbs. were required, whereas present catapults must supply energy at the rate of 27,000,000 to 54,000,000 ft.lbs. The heart of all modern catapults is the V-1, and the best modern catapult is the British steam model, which the United States is planning to produce.

The speaker definitely believes the "n.i.h." (not invented here) philosophy has no place in research, because the best available equipment must be obtained regardless of origin. Naval research has the responsibility of developing equipment and methods at the least

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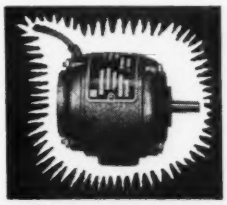

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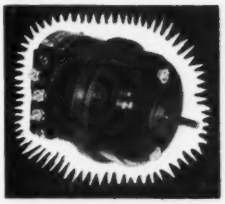

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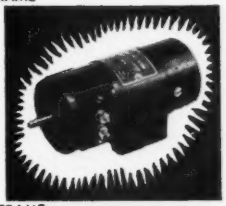

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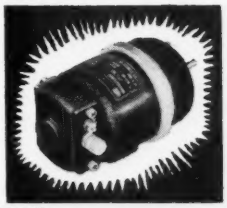

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Baltimore Section's Annual Spring Meeting: *A group of the Baltimore Section members and their wives and guests are shown before the Dinner Meeting held on June 3 at The Johns Hopkins University.*

expense consistent with worth-while results.

Concerning carrier landings, Admiral Bolster described the Davis nose wheel, which trips the arresting system and also the barrier net to stop the airplane without danger of decapitating the pilot.

At the conclusion of his speech, Admiral Bolster commented on movies showing two Cessna airplanes, one of which had boundary-layer control features, as they made approaches, landings, and take-offs.

After thanking Admiral Bolster for his entertaining talk, Mr. Jewett called upon Secretary M. F. Taylor who announced the results of the election of officers for 1952–1953. They are as follows: Chairman, A. J. Kullas; Vice-Chairman, J. P. Paine; Secretary, J. F. Maloney; Treasurer, L. F. Freitag; and Area Counselor, W. D. Van Zelm. The Advisory Board consists of W. W. Bender; W. A. Bortner; H. Pusin; M. F. Taylor; F. D. Jewett; W. W. Symington, Jr.; and G. S. Trimble, Jr.

Mr. Kullas then assumed his duties as Chairman and, after a few brief remarks, adjourned the meeting.

Buffalo Section

George B. Melrose, Jr., *June Program Committee Chairman*

Willy Ley, noted author, lecturer, and space travel authority, was the guest speaker at the sixth and closing meeting of the 1951–1952 season. The meeting was held on June 18 at the University of Buffalo and was cosponsored by the Niagara Frontier Rocket Society. Mr. Ley's interesting and informative address on "Man's Conquest of Space" was enthusiastically received by an audience of over 700 members and guests.

John van Lonkhuyzen, Chief of Technical Departments, Bell Aircraft Corporation, introduced the speaker. On the program committee were Les Fero, Bernie Goldman, Al Krivetsky, and George Melrose—Chairman.

Mr. Ley began his lecture with the history of the development of rocket engines—the power plant for space aircraft. He outlined the fundamental principles of jet propulsion and told of the early liquid-propellant rocket experiments that took place here and in Germany. Mr. Ley was one of the pioneers in rocket research and a founder of the German Rocket Society prior to coming to the United States in 1935. Successful rocket firings and flights were then few and far between. The rapid advances in the aeronautical field which were made during World War II and the period that has followed have pointed the way for the development of an artificial satellite or space station.

A colored film of the testing and firing of the Martin "Viking" test vehicle was shown as an example of current achievements. The Viking has reached an altitude of 250 miles which is approximately one-quarter of the 1,100-mile altitude proposed for the space station (2-hour orbit).

The speaker emphasized that no new basic discoveries are needed. The fundamental inventions have been made and need only to be applied toward the specific goal. In order to make space travel a reality, however, an extensive scientific effort will be required. Mr. Ley estimated that a manned space station could be designed and put into operation in 10 to 15 years for a total cost of between $3,000,000,000–4,000,000,000. Congress could get the project under way immediately by appropriating $300,000,000 annually, less than the current atomic-energy development budget. Some of the major problems arising in establishing a space station were discussed. Mr. Ley indicated that a three-stage rocket would be required, that the probability of meteoric damage is very remote, that cosmic dust particles should cause no serious problems, that medical experiments have already shown that pilots can tolerate the required acceleration rates and durations, etc.

The public is becoming increasingly aware of the advantages of a space station for observing enemy activities closely and as a launching platform for guided missiles. Mr. Ley emphasized that the need for beginning development of a space station is apparent and that it should be started now since we cannot afford to let some other nation dominate the world's skies.

Columbus Section

S. A. Gordon, *Secretary*

The second meeting of the Columbus Section was held at the Seneca Hotel on July 1. Approximately 50 guests and members were in attendance.

The meeting was preceded by a dinner. Chairman Dave Williams opened the business by calling for the usual reports, which were read and approved.

The speaker of the evening, Eugene T. Manganiello, gave a talk on research on supersonic propulsion, in which he pointed out that intensive effort is under way in all the principal aeronautical laboratories on problems associated with flight at supersonic speeds. Most intensive effort is being directed toward research on the propulsion systems for producing extremely high thrust. He pointed out that, while supersonic flight has already been achieved in research airplanes such as the X-1, further research is required to provide the basic data and design information for practical supersonic flight. An outline of the major problems in the supersonic propulsion field was presented, and some of the research efforts now in progress were given. The talk was illustrated by slides and a movie.

Mr. Manganiello's talk was enthusiastically received, and the meeting was adjourned at approximately 10:30 p.m.

Dayton Section

Charles L. Hall, *Secretary*

The May 28 meeting of the Dayton Section marked the end of a successful series of programs. Officers and members of the Advisory Board contributed

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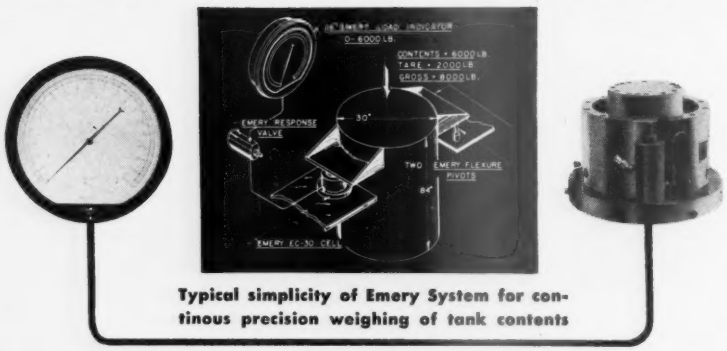

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toward the success of these meetings. Especially gratifying was the all-out effort by the Chairman, Lt. Col. Floyd Sweet, who not only conducted the meeting to everyone's satisfaction, but also contributed a considerable amount of his time to planning.

Our first meeting was held on September 26, 1951. Dr. R. C. Dehmel, of the Curtiss-Wright Corporation, presented his paper on the Curtiss-Wright flight simulators. An interesting colored film of the B-50 simulators in operation highlighted the event. Members who attended the meeting were pleased.

Our first field trip made the second meeting a big success. After an excellent dinner in the executive dining room at Wright-Patterson Air Force Base, Col. Jack Gibbs, Chief of Wright Air Development Center's Aircraft Laboratory, conducted tours of the wind tunnels. Demonstrations were presented, as well as commentary by W.A.D.C. engineers. The program was termed as excellent by those who attended.

Our November 28 meeting, third of the new year, featured Edgar Kaiser. This was a joint meeting with the Dayton Chapter, S.A.E. Mr. Kaiser's paper, "Conversion—A Permanent Policy," was thoroughly enjoyed by both memberships.

As usual, no December meeting was held because of the holiday season.

Our fourth meeting on January 23, 1952, turned out to be the most informative session of the year. An excellent paper entitled "Titanium—The New Metal for Aircraft" was presented by Dr. H. Adenstedt, Research Metallurgist with the Materials Laboratory, W.A.D.C. Many favorable comments were received on the treatment of this subject by the former German scientist.

On February 20, 1952, on the occasion of our fifth meeting, T. V. Grove and L. E. Alberts, of Minneapolis-Honeywell Regulator Company, presented their paper entitled "New Cockpit Concept for Auto-Pilot Utilization." This session was followed by a tour of the Dow-Corning exhibit of silicones and their uses.

Ernest Stout, Assistant to the Chief Engineer, Consolidated Vultee Aircraft Corporation, presented his "Review of High-Speed Hydrodynamic Development" at the March 26 meeting. A colored sound picture, as well as a number of interesting slides, illustrated to the members the value of using dynamically similar models in testing seaplanes' configuration. Mr. Stout pointed out several instances where large amounts of money were saved by Convair and the Navy through the use of these models. Several members viewed this development with its Air Force application in mind. The program was received with much enthusiasm by those who attended.

Always popular with the membership, our annual plant tour took place on April 23. More than 120 members and their guests attended the tour of General Electric Company's J-47 plant at Lockland, Ohio. Among the guests was Major General Putt, at that time Commanding General of Wright Air Development Center. This excellent tour was preceded by a good dinner and an informal presentation of the J-47 program by G-E engineers.

Bill Ivans, of international soaring fame, related his interesting experiences in flying the Sierra wave, as well as other soaring accomplishments, on the occasion of the May 28 meeting. A colored film and several interesting slides highlighted this presentation on the eve of the annual Wright Memorial Glider Meet. Needless to say, the program was well liked by those in attendance.

Hampton Roads Section

Albert L. Braslow, *Secretary*

At the May 14 meeting, approximately 85 members and guests heard Harry B. Horne, Jr., Manager of Engineering, Reaction Motors, Inc., talk on "Rocket Development and Application." After tracing the history of the development of the rocket from the Chinese "fire arrow" of the thirteenth century to the present-day solid and liquid propelled rockets, Mr. Horne spoke principally about the characteristics and detailed problems associated with bipropellant rockets.

One of the most challenging problems confronting the rocket-engine designer is that of providing sufficient cooling of the materials around the thrust chamber in which temperatures of 5,000 to 6,000°F. are generated. Methods that are currently being employed consist of sweat cooling, film cooling, or a regenerative cooling process with the use of one of the liquid propellants. When a rocket is used only once, as when applied to a missile, ceramic liners that will burn out are used in preference to the more expensive cooling procedures. The prime movers for propellant pumps, which rotate at from 7,000 to 30,000 r.p.m. and supply 400 gals. of fuel per min., are usually turbines actuated by the main rocket jets. The metallurgy problem associated with the turbine blades is another problem receiving considerable attention.

Mr. Horne stated that the design of the starting procedure for the bipropellant rocket was most difficult. It is necessary to have nearly perfect timing between the ignition and the flow of the two-liquid propellants in order to avoid the possibility of explosions. The propellant mixture ratio must be held close for both starting and steady-state opera-

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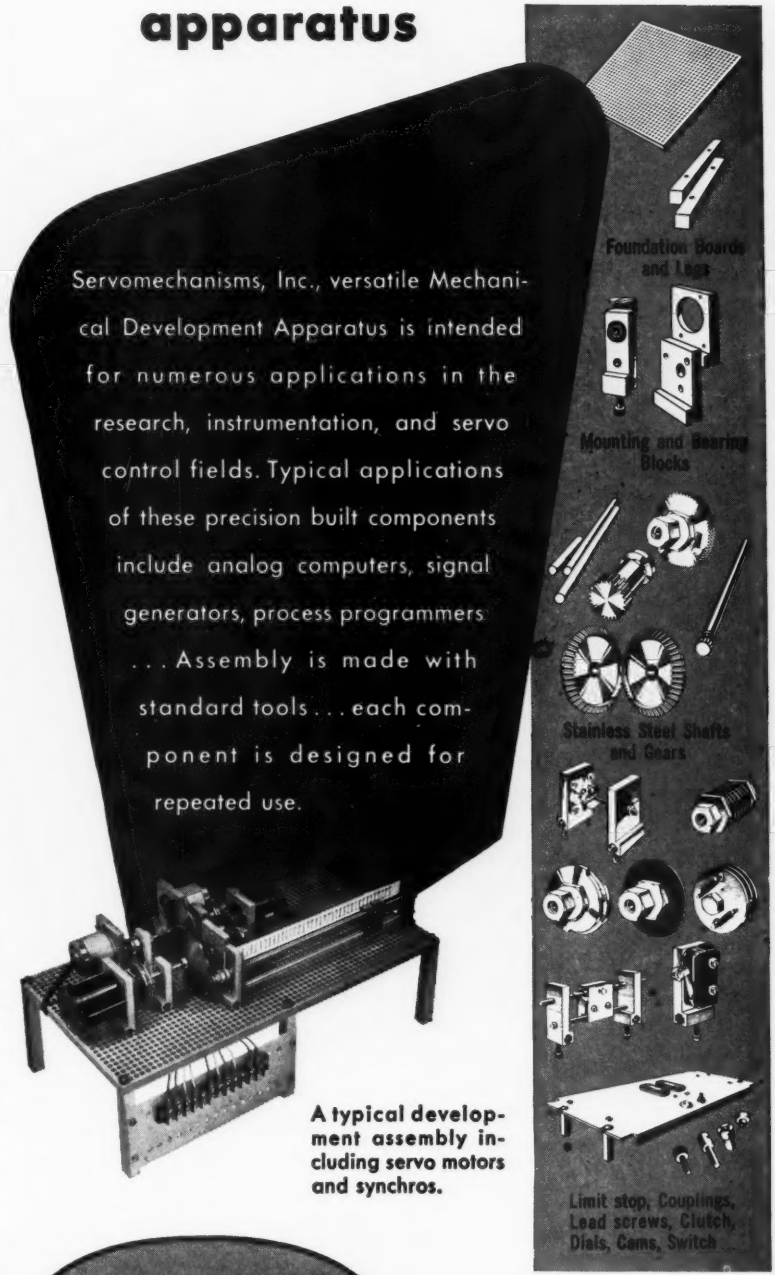
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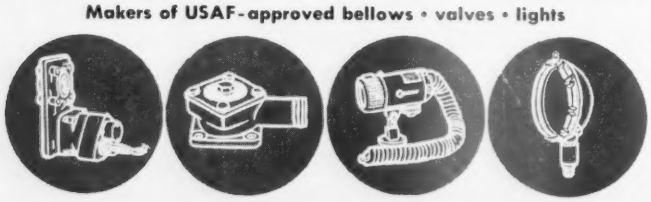

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tion, although the mixture ratio may not be the same for both conditions. The ignition system, itself, imposes many problems, and various methods are used. For one-shot affairs, a powder charge electrically ignited can be used. For re-use systems, Mr. Horne mentioned two types of ignitors—an auxiliary propellant that ignites by spontaneous combustion and a precombustion ignitor that consists of a bank of small rockets located ahead of the main rocket.

After presenting his opinions of relative merits of bipropellant, monopropellant, and solid propellant rockets, Mr. Horne concluded his talk with an interesting German movie of actual firings of the V-2 rockets during World War II.

▶ C. J. Wenzinger, Chief Engineer, Sverdrup and Parcel, Inc., addressed 109 members and guests on June 18. Special guests at the meeting were a large number of reservists in the Air Force Research and Development Command.

Mr. Wenzinger spoke about the Arnold Engineering and Development Center now under construction on a 33,000-acre tract of land in the T.V.A. area at Tullahoma, Tenn. The initial plans for the A.E.D.C. include three major technical facilities—engine test facility, gas dynamics facility, and propulsion wind-tunnel facility—which Mr. Wenzinger described.

The speaker went on to mention a few of the supporting service facilities that will be required and stated that some of these have already been completed or are under construction. These include a railroad extension, an internal railroad system, roads, bridges, shops, dispensaries, communication systems, fire and police stations, power dispatching center, computing center, a dam that will form a lake 12 miles in length to provide the necessary cooling water, and a canal 2 miles long that carries water from the dam to the site of the technical facilities with another canal to carry the water away. It will be necessary not only to cool the water before use in the various facilities, but also to cool the exhaust water in order not to harm the fishing potentialities for the local residents.

Mr. Wenzinger's talk was well illustrated with slides of the three technical facilities and of some of the various associated equipment. The large audience was left with a vivid impression of the almost overwhelming magnitude of the A.E.D.C., especially with respect to the high-powered propulsion wind-tunnel facility.

San Diego Section

H. L. Braasch, *Secretary*

The May 15 meeting was held at the Henry Langhorst Café, San Diego.

Following dinner, the members and guests adjourned to the Solar Aircraft Company's auditorium to hear a most interesting and enlightening lecture by Ernest Stout, of Consolidated Vultee Aircraft Corporation. Mr. Stout discussed in considerable detail the use of geometrically and dynamically similar models for free-flight determination of the flying qualities of prototypes. Mr. Stout's lecture included a discussion of high length/beam ratio hulls for flying boats as used on the Convair PB5Y-1 and also color motion pictures of the PB5Y-1 models being flight tested. A second motion picture was presented showing free-flight models of the "Skate," a transonic seaplane. This was followed by an explanation and description of the revolutionary hull of the Skate.

Approximately 80 members and guests attended the meeting.

Following the lecture, the meeting was adjourned by Chairman William Heath.

▶ On June 13, a meeting was held in the Marine Room of the Hotel San Diego. The dinner was preceded by a short social hour in the lounge.

The San Diego Section was fortunate to have as its speaker, Dr. Hugh L. Dryden, Director, N.A.C.A., who gave an interesting and enlightening talk on the subject, "Rocket Models and Other Techniques of Flight Research." Dr. Dryden's presentation covered all phases of the problem, including launching, free flight, telemetering, and data reduction. Much of the presentation included movies of rocket model flight tests, which were narrated by Dr. Dryden.

In addition to the movies of the rocket model tests, a film was also presented showing recent flight tests at Edwards Air Force Base, Calif.

After Dr. Dryden's presentation, Vice-Chairman R. P. White adjourned the meeting.

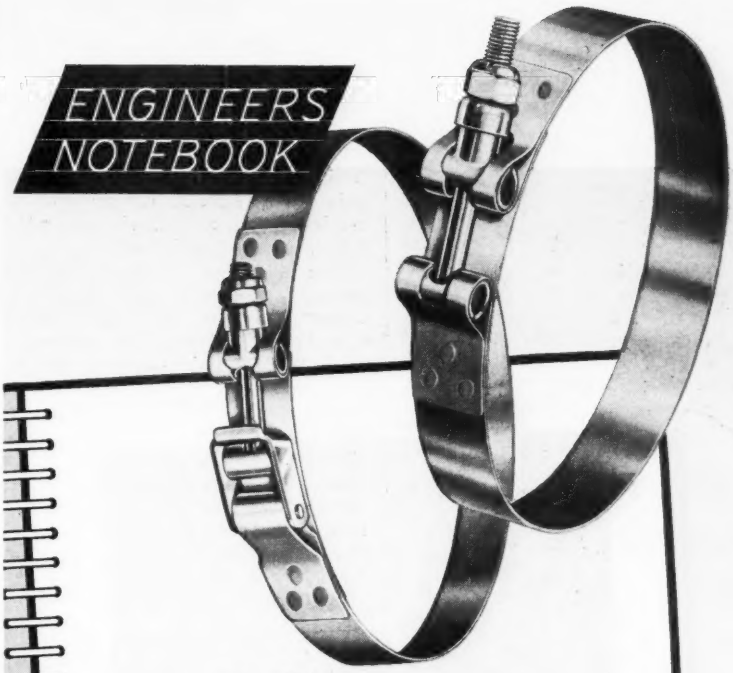
San Francisco Section

Forest W. Fingerle, *Secretary*

The meeting of June 19 was a Helicopter Symposium held at Ramor Oaks in Atherton. The Moderator was James B. Edwards, Chief Engineer, Hiller Helicopters.

Mr. Edwards prefaced the meeting by pointing out the importance of the helicopter as a valuable servant not only in military operations but also in the commercial fields. The increasing interest in helicopter design was also noted. He pointed out the importance of design with regard to maintenance and asked all engineers to be cognizant of this consideration.

George Brimball, Chief Service Engineer, Hiller Helicopters, was then pre-



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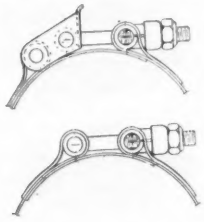

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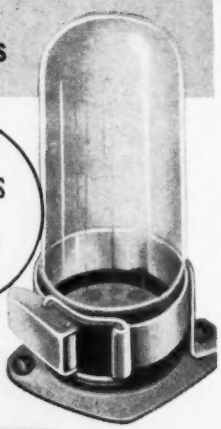

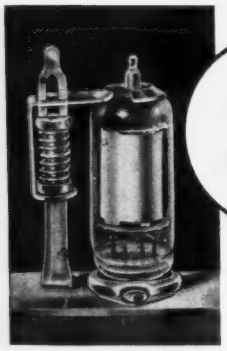

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sented as the first speaker of the evening. He emphasized the need for designers to consider the problems of wear in their designs. The need for adequate lubricating systems and correct lubricants was also noted. In this connection, he pointed out the low oxidation found in lithium-base greases. Mr. Brimball also pointed out some of the problems of servicing, such as balancing the rotor blades to keep them in track.

The Moderator announced that the second paper was on tandem-rotor helicopters because of the great interest of late in this type. He presented R. A. Wagner, Chief Engineer, McCulloch Motors, Inc. Mr. Wagner reviewed the program for the McCulloch helicopter and gave principal dimensions of the ship. The difference between the theoretical and actual loads on each rotor was given to point out the need for actual testing. Mr. Wagner also covered the problems of rudder and taxiing loads. He completed his paper giving advantages of tandem-rotor helicopters.

Mr. Edwards announced that the third paper, on future trends in passenger helicopters, was being presented in view of recent developments both here and abroad in large passenger-type helicopters. He introduced Joseph Stuart, III, Chief of Preliminary Design, Hiller Helicopters. Mr. Stuart brought out the features of commercial helicopters in various fields. Slides were shown of the various configurations now in production and proposed in this country. A short discussion was given of each type. He called attention to the developments in England of helicopters developed for commercial applications. Mr. Stuart discussed the pressure-jet engine now used and the jet engines now in development. The Rotodyne was discussed together with the convertiplane. The last slide shown was the short-range Hiller design.

The meeting was then opened for discussion during which time all three speakers were asked questions in their fields.

Seattle Section

R. D. FitzSimmons, *Secretary*

Roy E. Marquardt, President of Marquardt Aviation Company, addressed a members-only confidential meeting of the Seattle Section this past June 19. Speaking on the subject "Ramjet Engines and Their Application to Missiles and Aircraft," Mr. Marquardt limited his talk to the various types of ram-jets and indicated the place each occupies in the overall design picture. The talk centered around performance versus cost for all types of aircraft propulsion systems and was accompanied

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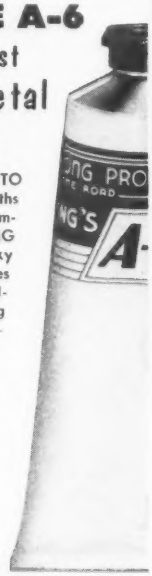

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by slides showing the polars and parameters of such systems. A technicolor movie showing testing of several ramjet engines followed.

Texas Section

Paul Alberti, *Secretary*

The May and June meetings of the Texas Section were in the form of field trips. On May 17, the Fort Worth plant of Consolidated Vultee Aircraft Corporation was visited. After being welcomed by W. A. Clegern, Chief of Engineering Flight Test, the members were taken on a conducted tour of the B-36 production line, and then were shown a movie depicting the role of the B-36 in strategic air warfare. Following the movie, there was a question and answer period on the design and production features of the B-36.

The next month, on June 21, the Chance Vought Aircraft Division of United Aircraft Corporation was toured. The meeting was opened with a short talk by Raymond Blaylock, after which the plant was toured and a movie illustrating the military use of the helicopter was shown. The final event was a flight demonstration of the F7U-1 Cutlass by John McGuyrt, Chance Vought Test Pilot, in conjunction with a scheduled test flight.

Student Branches

Academy of Aeronautics

At the June 18 meeting, Frey Mayer delivered an address on "Tailless Aircraft." His speech included the aerodynamic effects on the flying wing and was concluded with the advantages and disadvantages of such an aircraft. Two General Motor Corporation films, *We Drivers* and *Styling the Motor Car*, were shown at the conclusion of the meeting. Chairman Nickolus Kruger presided; 41 students were present.

▶ On July 16, Joseph Pasano spoke on the subject of "Convertiplanes." He reviewed the history of the convertiplane and went on to describe three types of convertiplanes and the companies concerned in their planning and construction. Chairman Nickolus Kruger presided; 38 students were present.

▶ On July 30, 36 persons were present at the election of officers for the forthcoming year. The results of these elections are as follows: Chairman, C. Grevera; Vice-Chairman, J. Cohen; Recording Secretary, H. Schub; Corresponding Secretary, F. Berger; Treasurer, E. Ladizensky; and Sergeant-at-Arms, J. Roman. Chairman Kruger presided.

A Visit to the Navy

By Frederick Berger, *Secretary*

On Wednesday, July 30, a five-car caravan of 26 members of the Academy's student branch set out to Sands Point, L.I., for a visit to the Special Devices Center, U.S. Navy.

We arrived at the base at approximately 10:15 a.m., and, after a check by the gate duty-sergeant, we were admitted inside the grounds. Once inside the base, we were courteously received by three Navy guides who led us to the exhibition hall. Before viewing the individual training devices, we were briefed as to the general scope of this installation. Its main function is to develop, evaluate, and improve a multitude of training machines, devices, and mock-ups used by the entire Navy's instructors corps to train personnel. This installation develops entirely new training facilities upon request from any Navy unit or else devises means and ways to make it easier to transmit the complicated duties of a modern Navy to its men.

After this brief outline, we were divided into three groups and were shown over the exhibition hall. Among the fascinating items we were permitted to see were:

(1) A special movie camera that projects a film upon a screen shaped in the form of a hollow quarter-sphere. This results in a vivid three-dimensional reproduction.

(2) A flight simulator consisting of a genuine replica of an aircraft's control board with levers for both student and instructor. A loud-speaker is connected to this simulator reproducing the engine sound effects present in an actual aircraft during various flight attitudes.

(3) A Navy gun for target practice, which is used in conjunction with a moving film projected on a screen, showing the target to be hit in the form of a small, white dot.

(4) An electronic device used to determine accurately the exactness of a pistol shot upon a target.

(5) A room shaped in semispherical form representing the sky extending from the horizon line to the zenith. By means of special light effects, one could reproduce the entire star picture and various other astronomical phenomena. This device is used for navigational purposes.

(6) A mock-up of a load adjuster used to determine pictorially the exact loading procedure of an aircraft.

(7) Several engine cutaways showing various types of aircraft engines in modern use.

(8) Several exhibits in the form of boards and mock-ups demonstrating pictorially various physical laws and determining mechanical efficiencies.

Our trip concluded shortly before 12 o'clock noon. Every participant was greatly impressed by what he had seen, and a most enjoyable morning was spent by all. Special thanks go to Mr. I. Fiorovanti, our faculty adviser, who handled our group in an excellent manner.

The Aeronautical University, Inc.

On June 26, 20 students went on a field trip to the Refinery and Research Laboratory of Standard Oil Company (Indiana). John L. Klucher, of Standard's Community Relations Department, acted as host. The trip was arranged by Vice-Chairman Lyman Welliver.

Indiana Technical College

At the June 10 meeting, J. P. Hughes, C.A.A. Aviation Safety Agent, spoke on "Helicopters and Convertiplanes." Mr. Hughes spoke briefly on the operation and practicability of the helicopter and convertiplane and discussed at length the various aspects of private and commercial flying as well as the increasing demands for aeronautical engineers in the aviation industry. Chairman Harold Swallow presided; 18 students were present.

A field trip to the Edison Museum in Dearborn, Mich., was held on June 20.

▶ At the meeting of July 8, two films were shown. They were *Hamilton Hydramatic Propeller* and *Fuselage Structures*. Chairman Harold Swallow presided; 13 students were present.

▶ An election of officers was held on August 5 with the following results: Chairman, Charles VanArtsdalen; Vice-Chairman, Roger Kauffman; Secretary, John Basile; and Treasurer, James Sanders. Chairman Swallow led the meeting with 14 persons present.

Northrop Aeronautical Institute

The officers for the 1952–1953 academic year are as follows: Chairman, Harold J. Robins; Vice-Chairman, Andrew R. Jessen; Treasurer, R. David McClelland; Recording Secretary, Ellsworth Hardy; and Corresponding Secretary, Jason L. Araujo. The Faculty Adviser is G. W. Blaisdell.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Jones, Robert T., Lecturer in Mech. Engrg., Stanford Univ.; Aero. Engr, Ames Aero. Lab., N.A.C.A.

Transferred to Associate Fellow Grade

Pope, Alan, M.S. in Ae.E., Supvr, Wind Tunnel Section, Sandia Corp.

Elected to MEMBER Grade

Barnett, Harry, B.S., Supvr., Funct. & Qual. Test Group, Lockheed Aircraft Corp. (Marietta).

Burns, Charles I., M.M.E., Engr., U.S. Army Ordnance (Washington, D.C.).

Davis, Thomas V., A.E., Sr. Group Engr., Boeing Airplane Co. (Seattle).

de Callies, Richard N., M.S., Lt. Comdr. & Naval Aviator, U.S.N.

Evaldson, Rune, Ph.D. in Engrg. Mechanics, Cons. Engr., Booz, Allen & Hamilton.

Gravendyk, James P., Engrg. Designer, Struct. Group, Special Weapons Div., Northrop Aircraft, Inc.

Johnson, Corydon M., Pres., Corydon M. Johnson Co., Inc.

Kinsler, Martin R., M.M.E., Research Asst., Dept. of Aero. Engrg. & Applied Mechanics, Polytechnic Institute of Brooklyn.

Papanek, Paul J., B.S., Mgr., Washington District Office, Jack & Heintz, Inc.

Pretorius, Thomas H., B.S., Aero Engr., Southern Air Procurement District.

Ray, James C., B.S.Ae.E., Layout Draftsman "B," Piasecki Helicopter Corp.

Smith, Charles H., Jr., B.S., Pres., The Steel Improvement & Forge Co.

Sternfield, Leonard, B.S., Head, Stability Analysis Section, Stability Research Div., N.A.C.A., Langley A.F.B.

Weitner, Walter L., Lt. Col.; Acting Chief, Fighter Section, Procurement Div., Hq., A.M.C., U.S.A.F.

Whempner, Russell H., B.Sc.E.E., Dir., Service Engrg. Dept., Minneapolis-Honeywell Regulator Co.

Wright, Gerald B., B.S., Sales Rep. to U.S.A.F., Sperry Gyroscope Co. Div., The Sperry Corp.

Transferred to MEMBER Grade

Graham, Glenn E., B.S., B.A., M.E., Group Engr., Prelim. Design, Boeing Airplane Co. (Seattle).

Montenegro, Carlos E., D.B., B.Sc., Associated Docent in Maintenance, Instituto Tecnologico de Aeronautica (Brazil).

Price, Donald H., M.S. in Ae.E., Sr. Aerodynamics Engr., Guided Missiles Div., Raytheon Mfg. Corp.

Siegel, Gordon I., B.S.Ae.E., Capt.; Chief, Equip. Br., B-47 Proj. Officer, Southern Air Procurement District Hqs., U.S.A.F.

Sutherland, Alexander E., B.A.Sc. in Ae.E., Sq. Engrg. Officer, 103rd Rescue Unit, R.C.A.F. Station, Greenwood, Nova Scotia.

Elected to Associate Member Grade

Andrus, Harold C., Div. Gen. Mgr., Lear, Inc. (Romec Div.)

McCann, Frank A., Jr., B.S.B.A., Contracts Administration Supvr., Aircraft Div., Rheem Mfg. Co.

Stutts, Arthur K., Boeing Maint. Staff Officer, Military Air Transport Service (Washington, D.C.).

Wehnes, W. C., V.-P. & Dir., Detroit Kellering Co.

Elected to Technical Member Grade

Cimino, Robert V., Engrg. Designer "B," North American Aviation, Inc. (Los Angeles).

Fogelson, Seymour, B.S., Stress Analyst "C," Aerophysics Dept., North American Aviation, Inc.

Hadari, Moshe, Second Flight Engr., Israel Natl. Airlines (Israel).

Hosse, Paul W., M.A., Electrical Draftsman, Fairchild Engine Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Klein, Robert C., B.E.E., Asst. Proj. Engr., Sperry Gyroscope Co. Div., The Sperry Corp.

Long, Bertram S., B.S., Instructor, Northeastern Univ.

Murphy, Maurice P., B.S.Ae.E., Flight Test Engr., Marquardt Aircraft Co.

Patterson, William R., M.S., Engr. 11, ARO, Inc.

Perry, Huntley H., B.S. in M.E., Aero. Engr. GS-7, Bur. of Aero., Dept. of the Navy (Washington, D.C.).

Rusinek, Edmund J., B.S. in Ae.E., Stress Analyst "B," Aerophysics Lab., North American Aviation, Inc.

Sherman, George J., Jr. Methods Engr., Radio Receptor Co., Inc.

Whitfield, Raymond P., Jr., B.S., Chief, & Capt., U.S.A.F., Flight Test & Acceptance Section, Govt. Aircraft Plant #4, Consolidated Vultee Aircraft Corp. (Ft. Worth).

Transferred to Technical Member Grade

Amano, Masashi R., B.S.M.E. (Aero.), Mech. Engr., Missile Aerodynamics Group, Hughes Aircraft Co.

Bacile, John I., B. of Ae.E., 2nd Lt., Corps of Engrs., U.S. Army (Ft. Belvoir).

Batchen, Frank L., B. of Ae.E., Vibration Flight Test Engr., Propeller Div., Curtiss-Wright Corp.

Batten, Robert L., Jr. Engr., Consolidated Vultee Aircraft Corp. (San Diego).

Benson, Burtis R., B.S. in Ae.E., Lt., U.S.A.F.; Student, Institute of Technology, Wright-Patterson A.F.B.

Berger, Alan, B. of Ae.E., 2nd Lt., U.S.A., Corps of Engrs. (Ft. Belvoir).

Billerbeck, Wilfred J., B. of Ae.E., Aerodynamicist, Vitro Corp. of America.

Bissell, William S., B.S., Jr. Engr., Draftsman "B," Lockheed Aircraft Corp. (Burbank).

Blackburn, Albert W., M.S. in Ae.E., Capt., U.S.M.C.R.; Member, Planning Div., Armament Test Dept., N.A.T.C. (Patuxent River).

Boxenhorn, Burton, B.M.E., Research Engr., Thermodynamics Section, United Aircraft Corp. (East Hartford).

Bradley, Edward P., B.S. in Ae.E., Aerodynamicist "C," McDonnell Aircraft Corp.

Brady, Gerald R., A.A., Flight Test Analyst "A," Aerophysics Lab., North American Aviation, Inc. (Downey).

Brueger, John M., B. of Ae.E., Ens., U.S.N.; Line Officer assigned to U.S.S. "Mississippi."

Burggraf, Odus R., Jr., M.S., Graduate Student, California Institute of Technology.

Cliffe, Richard T., Jr., B.S., Aerodynamicist, North American Aviation, Inc. (Los Angeles).

Coppi, Charles N., B. of Ae.E., Designer—Guided Missiles, Grumman Aircraft Engrg. Corp.

Costa, Rinaldo, B. of Ae.E., Aerodynamicist, Grumman Aircraft Engrg. Corp.

Covert, Henry E., Jr., B.S., Tech. Analyst, McDonnell Aircraft Corp.

Covey, Robert E., M.S. in Ae.E., Proj. Engr., Jet Propulsion Lab., California Institute of Technology.

Curtiss, Howard C., Jr., B. of Ae.E., Ens., U.S.N.R.; Line Officer, U.S.S. "Mississippi" (EAG-128).

Davis, William S., B.S. in Ae.E., Engr., Devel. Group, Chance Vought Aircraft Div., United Aircraft Corp.

Dervishyan, Aram, Prof. of Aero. Engrg., California Institute of Technology.

Doner, John E., A.E., Engr., Aircraft Armaments, Inc.

Eber, Lloyd W., B.S. in Ae.E., Draftsman "B," United Air Lines.

Fetterman, David E., Jr., B.S., Aero. Research Intern, N.A.C.A., Langley A.F.B.

Freeman, Elmer C., M.S.E., Capt., U.S.A.F.; Proj. Officer, W.A.D.C., Wright-Patterson A.F.B.

Gaibler, Richard, A.E., Lt., U.S.N.; Line Officer-Naval Aviator (Washington, D.C.).

Gandy, Charles L., Jr., M.S.E. (Aero.), Capt., U.S.A.F.; assigned to Flight Test Center, Edwards A.F.B.

Gatje, George C., B. of Ae.E., Ens., U.S.N.; Main Propulsion Asst., Engrg. Dept., U.S.S. "Preston."

Gentile, Joseph, B. of Ae.E., Test Engr., Wright Aero. Div., Curtiss-Wright Corp.

Goldman, Kenneth L., B.S.M.E. (Aero.), Research Fellow, Dept. of Aero. Engrg., Polytechnic Institute of Brooklyn.

Gomez, Jess C., B.S., Jr. Engr.-Draftsman "B," Lockheed Aircraft Corp.

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- **high fatigue strength and endurance limit for non-ferrous, corrosion-resisting materials**
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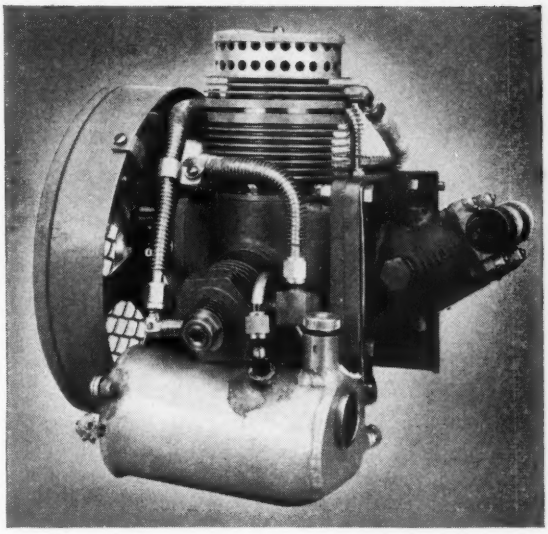
Developed for pneumatically-operated airborne equipment, this lightweight compressor has neither connecting rods, wrist pins nor other complications required by conventional design. Instead, a crankshaft-riding cam simply pushes the pistons into their cylinders. A scotch yoke and sliding rod reverses the first piston while compressed air from preceding stages retracts the others.

For the disc valve in the first stage which is intricately shaped and then heat treated, the design engineers of Walter Kidde & Company, Inc., specified age-hardenable Duranickel. They also called for Duranickel for valve assist springs.

Mechanical Property Ranges of Duranickel

Form and Condition	Tensile Strength 1000 psi.	Yield Strength (0.2% offset) 1000 psi.	Elongation in 2 in. per cent	Hardness Rockwell C
Rod and Bar				
Hot-finished	90-130	35-90	55-30	75B-22
Hot-finished, age-hardened	160-200	115-150	30-15	32-42
Cold-drawn, as-drawn	110-150	60-130	35-15	90B-32
Cold-drawn, age-hardened	170-210	125-175	25-15	32-42
Strip				
½ hard	130-155		15-3	25-34
½ hard, age-hardened	170-210		20-7	33-42
Spring	155-190		10-2	30-40
Spring, age-hardened	180-230		15-5	36-46
Wire				
Spring	160-200		5-2	
Spring, age-hardened	200-240		10-5	



NEW COMPRESSOR delivers volume at high altitudes. At 35,000 feet, this 4-stage, 4-piston air compressor delivers (from ambient pressure) one cfm of free air compressed to 3,000 psi. Its sea level delivery of 4 cfm of free air compressed to 3,000 psi can be maintained at high altitudes when inlet air is pressurized. The compressor weighs only 15 pounds, has first-stage valve of Duranickel, and Duranickel assist springs to insure closing of intake valves. *Photo courtesy of Walter Kidde & Company, Inc., Belleville, N. J.*

Duranickel is well able to withstand the high temperatures encountered in meeting the severe requirement. It is not affected by moisture squeezed out of the air during compression. And it offers high strength to prevent warpage.

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Meanwhile, keep Duranickel in mind for any applications where corrosion resistance, high hardness and great strength are needed in high stress application. Remember, though, that Duranickel, like other nickel alloys, is now on extended delivery because of defense requirements. So it is important to include NPA rating and complete end-use information when you place orders.

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Martin, Luc A., B.S.

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McNeely, James S., B.S., Ens. & Naval Aviator, U.S.N.

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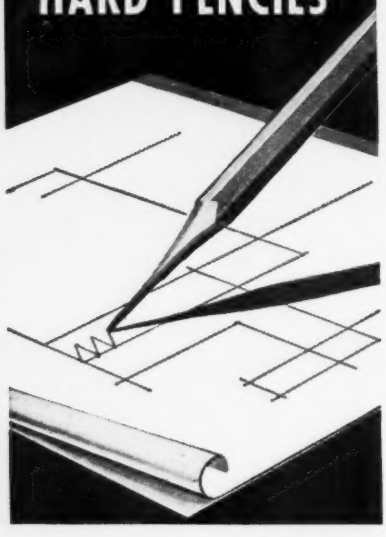

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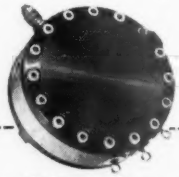

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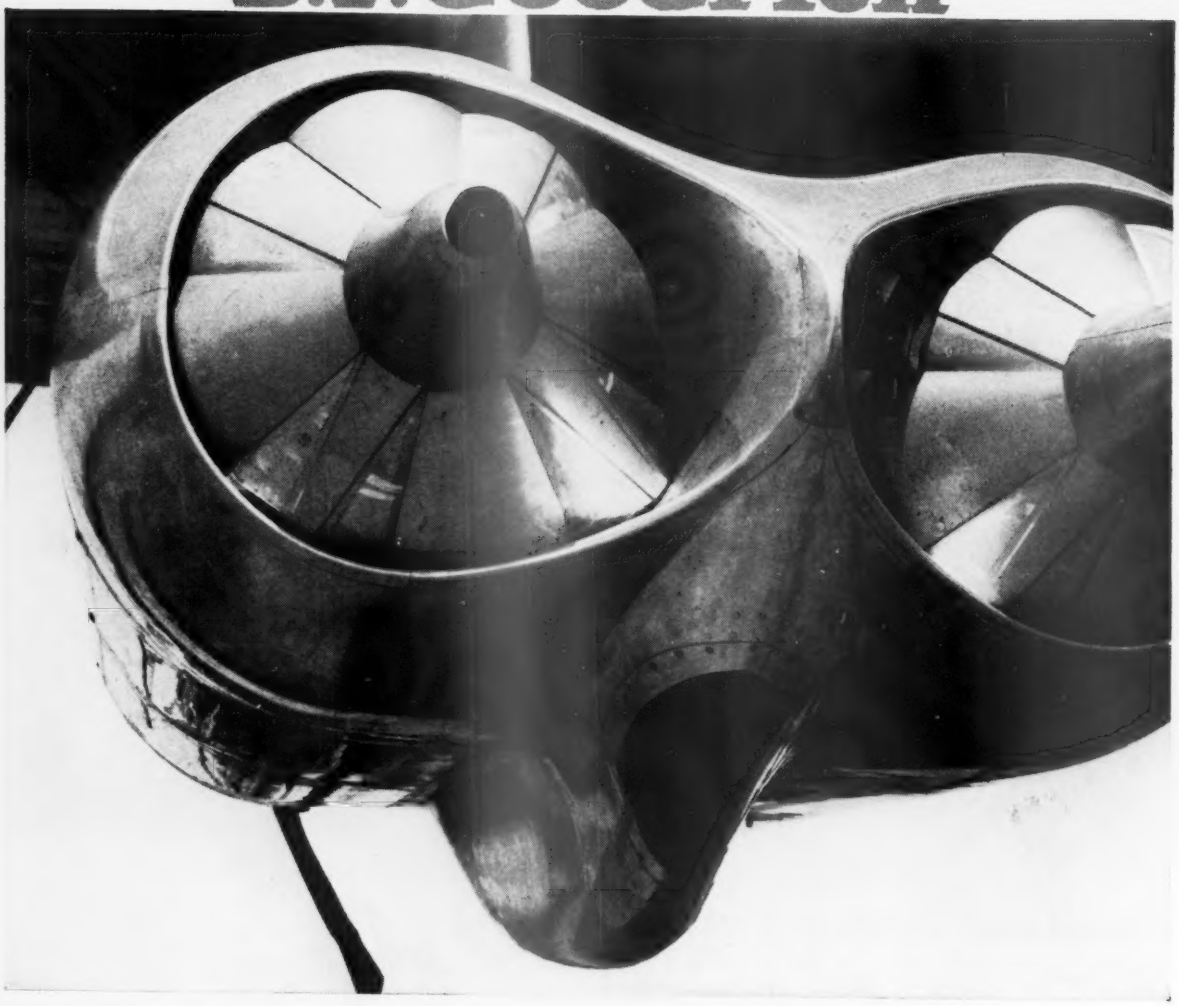

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A Guide to the Current Literature of Aeronautical Research and Engineering

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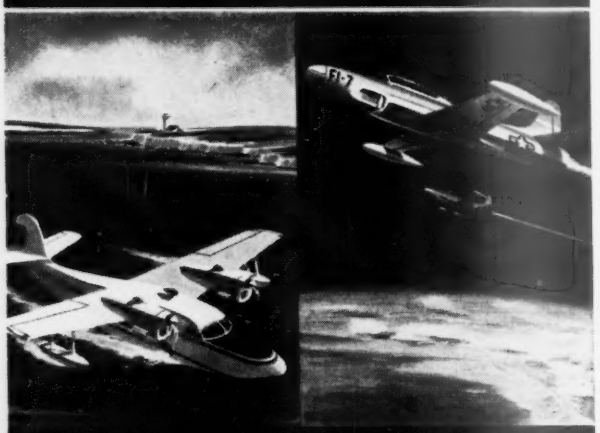

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Aerodynamics (2)

BOUNDARY LAYER & THERMOAERODYNAMICS

Power Requirements for Distributed Suction for Increasing Maximum Lift. R. C. Pankhurst and N. Gregory. *Gt. Brit., Aeronautical Research Council, Current Papers No. 82*, 1952 (September 7, 1948). 7 pp., illus. 4 references. British Information Services, New York. $0.50. Analysis of the power economy of boundary-layer control by suction through a porous surface.

Readers' Forum: Heat Transfer Near the Forward Stagnation Point of a Body of Revolution. M. Sibulkin. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 570, 571. 2 references. Development of a theoretical solution for the heat transfer near the forward stagnation point of a body of revolution in laminar, incompressible, subsonic flow.

Readers' Forum: A Graphical Method for Determining Exact Boundary-Layer Temperatures. J. J. Martin. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, p. 576, illus. 1 reference.

A Solution of the Laminar Boundary-Layer Equations for a Compressible Fluid with Variable Properties, Including Dissociation. L. L. Moore. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 505–518, illus. 15 references.

Solution of the laminar boundary-layer equations for a flat plate; the analysis covers an evaluation of skin-friction and heat-transfer characteristics for both the insulated plate and the heat-transfer cases over a Mach Number range of 1 to 20. The equations are reduced to forms suitable for solution with analog computers.

Simplified Laminar Boundary-Layer Calculations for Bodies of Revolution and for Yawed Wings. Nicholas Rott and L. F. Crabtree. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 553–565, illus. 45 references.

Extension of momentum methods in boundary-layer calculations to elementary three-dimensional cases and to compressible laminar boundary-layer calculations; brief analysis of the corresponding problems for the turbulent boundary layer.

Readers' Forum: Equations for Estimating Laminar Boundary-Layer Effects. Ralph Ashby Burton. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 573, 574, illus. 1 reference.

FLUID MECHANICS & AERODYNAMIC THEORY

Extension to the Cases of Two-Dimensional and Spherically Symmetric Flows of Two Particular Solutions to the Equations of Motion Governing Unsteady Flow in a Gas. Lorenzo Poggi. (*L'Aerotecnica*, Vol. 31, No. 1, February 15, 1951, pp. 90, 91.) *U.S., N.A.C.A., Technical Memorandum No. 1332*, June, 1952. 6 pp. 1 reference.

Readers' Forum: Fluid Motions Whose Kinematics Are Independent of Compressibility of Fluid. H. G. Loos. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, p. 576, illus. 1 reference.

On the Particular Integrals of the Prandtl-Busemann Iteration Equations for the Flow of a Compressible Fluid. Carl Kaplan. (*U.S., N.A.C.A., Technical Note No. 2159*, 1950.) *U.S., N.A.C.A., Report No. 1039*, 1951. 6 pp. 3 references. Superintendent of Documents, Washington. $0.15.

Translational Motion of Bodies Under the Free Surface of a Heavy Fluid of Finite Depth. M. D. Haskind. (*Prikladnaia Matematika i Mekhanika*, Moscow, Vol. 9, September, 1945, pp. 67–78.) *U.S., N.A.C.A., Technical Memorandum No. 1345*, June, 1952. 20 pp., illus. 3 references.

Analysis of the two-dimensional case of the wave motion produced in a heavy fluid of finite depth by the horizontal rectilinear and uniform motion of a solid body of arbitrary shape immersed in the fluid, assuming that the motion of the fluid is potential and steady relative to the body.

Experimental Investigation of the Effects of Viscosity on the Drag and Base Pressure of Bodies of Revolution at a Mach Number of 1.5. Dean R. Chapman and Edward W. Perkins. (*U.S., N.A.C.A., Research Memorandum No. A7A31a*, 1947) *U.S., N.A.C.A., Report No. 1036*, 1951. 24 pp., illus. 21 references. Superintendent of Documents, Washington. $0.25.

The Effect of High Viscosity on the Flow Around a Cylinder and Around a Sphere. F. Homann. (*Zeitschrift für angewandte Matematik und Mechanik*, Vol. 16, No. 3, June, 1936). *U.S.*,

N.A.C.A., Technical Memorandum No. 1334, June, 1952. 20 pp., illus. 2 references.

Interferometric Analysis of Airflow About Projectiles in Free Flight. F. D. Bennett, W. C. Carter, and V. E. Bergdolt. *Journal of Applied Physics*, Vol. 23, No. 4, April, 1952, pp. 453–469, illus. 14 references.

An adaptation to the ENIAC of the interferogram reduction problem for axisymmetric flow; comparison of isopycnal charts from interferograms of projectiles in free flight with similar studies employing fixed models in a wind tunnel or a circular jet; analysis of sources of error.

Heat Conduction in a Compressible Fluid. J. D. Cole and T. Y. Wu. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 209–213, illus. 3 references.

A study of some exact equations of motion and heat transfer in a compressible fluid, neglecting the effects of viscosity and assuming that all disturbances are small.

Flow Characteristics over a Lifting Wedge of Finite Aspect Ratio with Attached and Detached Shock Waves at a Mach Number of 1.40. John H. Hilton, Jr. *U.S., N.A.C.A., Technical Note No. 2712*, June, 1952. 21 pp., illus. 20 references.

Data, obtained in the Langley 4- by 4-ft. supersonic tunnel at M = 1.40, showing the effect of transition from an attached to a detached shock at the leading edge of an 8.2° wedge airfoil as the angle of incidence is increased.

A Vector Study of Linearized Supersonic Flow; Applications to Nonplanar Problems. John C. Martin. *U.S., N.A.C.A., Technical Note No. 2641*, June, 1952. 79 pp., illus. 15 references.

Presentation of a vector derivation of general flow-study results obtained by various methods; derivation of a hyperbolic scalar potential and a hyperbolic vector potential; vector analysis of problems concerned with planar bodies in supersonic flow; derivation of methods of solutions for problems dealing with nonplanar systems.

Readers' Forum: Comments on "A Study of Transonic Gas Dynamics by the Hydraulic Analogy" by E. V. Laitone. W. C. Randels. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, p. 572. 2 references.

Diffusion in a Field of Homogeneous Turbulence. II—The Relative Motion of Particles. G. K. Batchelor. *Cambridge Philosophical Society, Proceedings, Vol. 48*, Part 2, April, 1952, pp. 345–362, illus. 6 references.

Analysis of the relative diffusion of the particles in a cloud of marked fluid in which the statistical history of the particles in diffusion is determined under the action of infinite, homogeneous turbulence.

The Spectra of Turbulence in a Compressible Fluid; Eddy Turbulence and Random Noise. J. E. Moyal. *Cambridge Philosophical Society, Proceedings*, Vol. 48, Part 2, April, 1952, pp. 329–344. 15 references.

Mechanism of Turbulent Fluid Motion. Max Munk. *Aero Digest*, Vol. 64, No. 6, June, 1952, pp. 32, 34, 36, 38, 40, 42, 44, 46, 48, illus.

INTERNAL FLOW

Rotational Effects on a Cascade of Aerofoil Blades. K. H. Khalil. *The Engineer*, Vol. 193, No. 5030, June 20, 1952, pp. 831–834, illus. 7 references.

A wind-tunnel investigation of the effects of rotation on the flow around blades of airfoil shapes; comparison with results for the same blades under static conditions.

Researches on Straight Wing Lattice. Gorō Kanamoto. *Japan Science Review*, Vol. 2, No. 1, April, 1951, pp. 89–106, illus.

An analysis in which the theory of wings in nonuniform flow is used to explain the effects of the number of airfoils and the boundary conditions of flow for cascades in flows bounded by fixed walls, by a free jet, by fixed walls and free jet, and by fixed walls at the inlet and movable walls at the exit.

The Supersonic Axial Compressor. J. E. B. Perkins. *Shell Aviation News*, No. 167, May, 1952, pp. 20, 21, illus. Advantages of the axial compressor as compared with the centrifugal compressor for supersonic flight; problems in the development of the supersonic axial compressor.

Whirling of a Bladed Disc. John L. Bogdanoff. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 519–528, illus. 1 reference. Analysis of the influence of elastic blades on the whirling natural frequencies of a bladed disc mounted on a cantilever shaft.

Designing a Slot for a Given Wall Velocity. A. Thom and Laura Klanfer. *Gt. Brit., Aeronautical Research Council, Current Papers No. 76*, 1952 (December 18, 1950). 12 pp., illus. 3 references. British Information Services, New York. $0.50.

Procedure for the arithmetical calculation of the wall shape of an expanding passage with specified constant wall velocities in which a slot withdraws fluid from the passage, of the slope of the slot entry, and of the effect on the velocity field of rounding the cusp that develops at the entry. The passage is symmetric and has an entry velocity of e (2.718) and an exit velocity of 1.

Measurement of Recovery Factors and Friction Coefficients for Supersonic Flow of Air in a Tube. II—Results Based on a Two-Dimensional Flow Model for the Entrance Region. J. Kaye, T. Y. Toong, and R. H. Shoulberg. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 185–194, illus., tables. 8 references.

Three-Dimensional Supersonic Nozzles and Inlets of Arbitrary Exit Cross Section. John C. Evvard and Stephen H. Maslen. *U.S., N.A.C.A., Technical Note No. 2688*, April, 1952. 12 pp., illus. 6 references.

Development of a simple procedure, exact within the limits of the method of characteristics, for obtaining three-dimensional unsymmetric supersonic nozzles and inlets from known axisymmetric flows.

PERFORMANCE

Estimating Takeoff Run. Philip R. Conrath. *Aero Digest*, Vol. 64, No. 6, June, 1952, pp. 62, 64–66, 68, 70, illus. Mathematical procedure for calculating the aircraft take-off ground run.

STABILITY & CONTROL

Use of Negative Camber in the Transonic Speed Range. W. F. Hilton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2460*, 1952 (March 8, 1947). 5 pp., illus. 2 references. British Information Services, New York. $0.50.

Analysis of the problem of balancing an aircraft for stable horizontal flight in the transonic speed range (M = 0.8–1.2); use of negative camber on the wing and tail surfaces to minimize the effect of trim changes caused by a sudden loss of lift which result in a nose-heavy dive.

An Analysis of the Pitching Motion of an Aeroplane Due to Sideslip. A. J. Marx and J. Buhrman. *Netherlands, Nationaal Luchtvaartlaboratorium, Amsterdam, Report No. V.1602* (*Reports and Transactions*, Vol. 16, pp. V1–V6), 1951. 6 pp., illus. 3 references.

Development of a method for determining the disturbed motion of an aircraft following a sudden rudder deflection or failure of an asymmetrically placed engine; establishment of a criterion for evaluating the pitching behavior due to sideslip.

Prediction of Yawing Stability Characteristics of Airplanes During Catapulting. Henry J. Kelley. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 529–539, illus. 7 references.

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A Study of the Use of Experimental Stability Derivatives in the Calculation of the Lateral Disturbed Motions of a Swept-Wing Airplane and Comparison with Flight Results. John D. Bird and Byron M. Jaquet. (*U.S., N.A.C.A., Technical Note No. 2013*, 1950). *U.S., N.A.C.A., Report No. 1031*, 1951. 25 pp., illus. Superintendent of Documents, Washington, $0.25.

WINGS & AIRFOILS

The Solution by Lifting-Line Theory of Problems Involving Discontinuities. V. M. Falkner. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2592*, 1952 (October, 1947). 23 pp., illus. 4 references. British Information Services, New York. $1.50.

A preliminary report on the procedure for solving wing-loading problems involving discontinuities by the lifting-line theory, considering four discontinuities: direction of leading or trailing edge, incidence, two-dimensional lift slope, and chord. The analysis is limited to wings in straight unyawed flight and includes lift, induced drag, and pitching, rolling, and yawing moments. Forma-

tion of the equations and solutions for a representative range of problems for a hypothetical wing are fully explained. The analysis deals only with the potential solutions obtained by the lifting-line theory, with no specification of correction factors for viscosity.

Notes on the Designing of Subsonic Aerofoils by Means of Ideal Fluid Theory. Tahito Ishida. *Japan Society for Applied Mechanics, Journal*, Vol. 5, No. 26, February, 1952, pp. 7–10. 7 references.

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Pressure distributions of the flow about a 30 per cent thick Griffith airfoil with air ejection at the slots, at Reynolds Numbers of 0.96, 1.92, and 2.88×10^6 at various angles of attack and flap settings; comparison of the lift characteristics and drag reductions obtained with air ejection with those obtained with suction.

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A catalog of airfoils that have been designed (or substantially modified) at the National Physical Laboratory and which have been the subject of theoretical investigations, aircraft design studies, or wind-tunnel tests, excluding wing sections designed specifically for aircraft companies; a list of 121 references on these airfoils. Each airfoil is assigned an N.P.L. reference number, and they are classified according to design studies.

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Study of Effects of Sweep on the Flutter of Cantilever Wings. J. G. Barmby, H. J. Cunningham, and I. E. Garrick. (*U.S.*,

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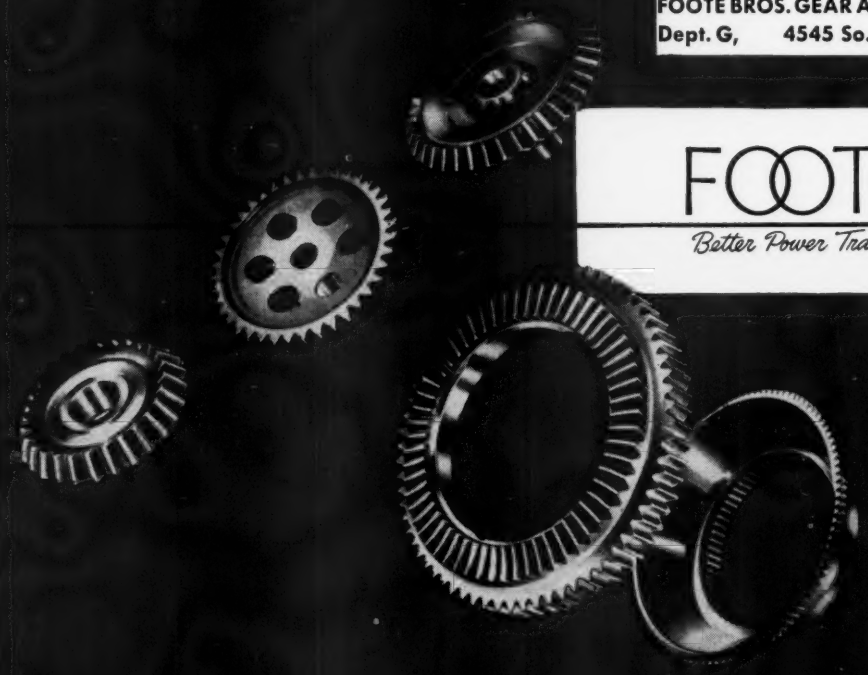

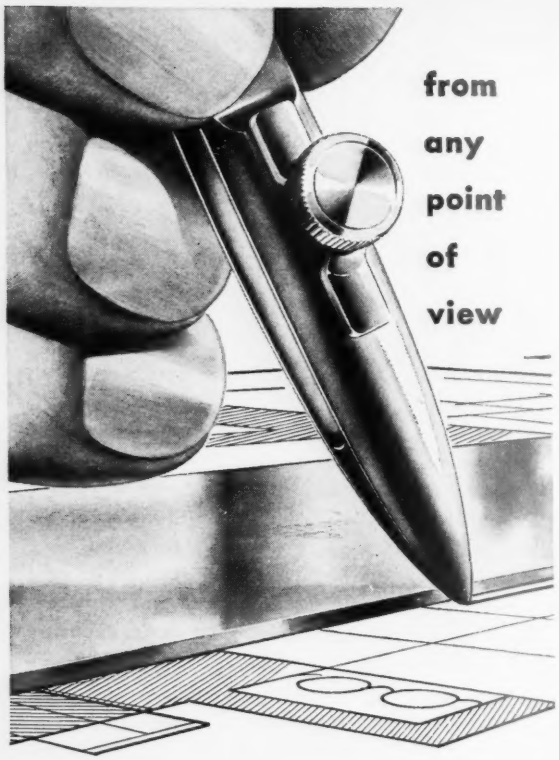

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Slick Airways and U.S. Air Freighting. *Shell Aviation News* No. 165, March, 1952, pp. 4–6, illus.

Types of freight carried and types of aircraft used by Slick Airways; comparison of freight rates with those of Air Express and rail express; experience with Douglas DC-6A's; possible effects of turboprop-engined aircraft and new fuels on rate reduction.

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AIR CONDITIONING & PRESSURIZATION

Complete Control for DC-3 Heating. *American Aviation*, Vol. 16, No. 3, July 7, 1952, pp. 44, 46, illus.

Construction and operation of a fully automatic heat control system designed by the Vapor Heating Corp. for the Douglas DC-3. The system incorporates electric actuators that adjust the mixing valves in response to mercury contact thermostat located in the heating ducts, cockpit, and cabin.

AIRPLANE DESCRIPTIONS

The Research Airplane. Walter T. Bonney. *Pegasus*, Vol. 18, No. 6, June, 1952, pp. 1–15, illus.

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Lockheed Model 1049G Super Constellation Four-Engined Transport Aircraft. *American Aviation*, Vol. 16, No. 5, August 4, 1952, pp. 18, 19, illus.

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Prone Flying. Fritz von Hermann. (*Thermik*, Vol. 5, Nos. 1–3, January–March, 1952.) *Sailplane and Glider*, Vol. 20, No. 6, June, 1952, pp. 5–7, illus.

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Cockpit Instrument Panel Standardized. M. G. Beard. *SAE Journal*, Vol. 60, No. 6, June, 1952, pp. 50, 51, illus. Standard layouts for cockpit instrument panels, as developed by the SAE Cockpit Standardization Committee S-7.

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(Martin-Baker) Ejection-Seat. II—Main Sheet-Metal Subassemblies and Seat-Raising Mechanism. H. J. Pearson. *Aircraft Production*, Vol. 14, No. 164, June, 1952, pp. 208–214, illus.

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Dunlop Maxaret Unit; Anti-Skid Device for Aircraft Brakes. *Shell Aviation News*, No. 165, March, 1952, pp. 14–16, illus.

Construction and operation of Dunlop Maxaret Unit for automatic brake control which prevents wheel locking on high performance aircraft; flight experience. The unit can be installed on the brake without any additional structure or linkage.

OPERATION & PERFORMANCE

The Future of Turbine-Powered Transport Aircraft. R. J. Templin. *Canada, National Research Council, Aeronautical Laboratories, Quarterly Bulletin, Report No. NAE 1952 (1)*, January 1–March 31, 1952, pp. 1–5, illus.

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Development of expressions for an optimum range technique for jet aircraft cruise control; comparison with piston-engine techniques; method of presenting and applying jet engine data in nondimensional form for simplifying the analysis, calculation, and presentation of jet aircraft performance data.

Economic Aspects of the Supersonic Jet Transport. Robert E. Hage and Richard D. Fitzsimmons. *Aeronautical Engineering Review*, Vol. 11, No. 9, September, 1952, pp. 42–45, illus. Analysis of the aircraft design parameters that affect aircraft range and determine the weight and direct operating costs of supersonic jet transports.

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Handley Page Hastings C. Mk. 1 Four-Engined Transport Aircraft, England (The Effects of Atmospheric Humidity and Temperature on the Engine Power and Take-Off Performance of a Hastings 1). G. Jackson. *Gt. Brit., Aeronautical Research Council, Current Papers No. 77*, 1952 (February 9, 1950). 34 pp., illus., folding charts. 10 references. British Information Services, New York. $1.40. Flight tests to determine the effects of

changes in humidity and air temperature on engine power, fuel flow, and aircraft take-off performance.

North American F-86 Sabre Single-Engined Turbojet Fighter Aircraft. *Aviation Week*, Vol. 56, No. 26, June 30, 1952, pp. 52–54, illus. Combat evaluation.

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Vampire Canopy; The Construction of the de Havilland Night-Fighter Cockpit Enclosure. I—Castings. *Aircraft Production*, Vol. 14, No. 164, June, 1952, pp. 186–190, illus.

WING GROUP

A Variable-Shape Aeroplane. W. H. Sayers. *The Aeroplane*, Vol. 82, No. 2135, June 20, 1952, pp. 749–752, illus.

An analysis of the practicability of the design patented in Britain by L. E. Baynes for a supersonic single-place aircraft powered by two Rolls-Royce Avon turbojet engines. The wings are hinged to the fuselage and can be folded and unfolded in flight permitting a sweepback variation up to 60°, in order to obtain optimum correlation of sweepback with flight speed.

Airports (39)

Performance Characteristics of Jet Aircraft and Requirements of Air Traffic Control. *Aeronautical Society of India, Journal*, Vol. 4, No. 1, February, 1952, pp. 27–31, illus. 4 references.

Problems of air-traffic control at high speeds and altitudes; proposed requirements to insure safe and economical operation of jet aircraft on regular commercial air routes.

Air Traffic Control System. George Heath. *Electronics*, Vol. 25, No. 6, June, 1952, pp. 152, 154, illus.

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What About Tomorrow's Heliports? Lois C. Philmus. *American Aviation*, Vol. 16, No. 5, August 4, 1952, pp. 32, 33, illus. Planning considerations and procedures for heliports; preliminary heliport design criteria.

Will "Stratoports" Solve Airport Problems? Joseph S. Murphy. *American Aviation*, Vol. 16, No. 4, July 21, 1952, p. 22, illus. Design plan for a Stratoport which features undirectional runways that are protected by 50-ft. V-shaped wind-absorbing fences.

Aviation Medicine (19)

Eye Fixations of Aircraft Pilots. VII—Fixations During Day and Night GCA Approaches Using an Experimental Panel Arrangement. John L. Milton, Billy B. McIntosh, and Edward L. Cole. *U.S., Air Force, Technical Report No. 6709*, February, 1952. 35 pp., illus. 8 references.

Design for Zero "G"; A Man-Carrying Rocket for Physiological Research in Near Space. K. W. Gatland. *Flight*, Vol. 61, No. 2266, June 27, 1952, pp. 774, 775, 779, illus. A proposal for research into the physiological effects of weightlessness and for a man-carrying research rocket designed to produce the required data.

Computers & Simulators

Modern Computing Machines. G. Truman Hunter. *Franklin Institute, Journal*, Vol. 253, No. 6, June, 1952, pp. 568–583, illus.

Brief history of the development of modern large-scale high-speed digital computers; types of storage systems and of systems and units for input-output operation; design features and operation of several digital machines.

Universal High-Speed Digital Computers; A Magnetic Store. F. C. Williams, T. Kilburn, and G. E. Thomas. (*I.E.E., Measurements Section, Paper No. 1191.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 99, No. 68, April, 1952, pp. 94–106, Discussion, pp. 120–123, illus. 13 references.

Elements, construction, and principles of operation of an experimental magnetic-drum storage system with a capacity of 3,000 numbers, each of 40 binary digits, developed for the Manchester University digital computer.

Universal High-Speed Digital Computers; Serial Computing Circuits. F. C. Williams, A. A. Robinson, and T. Kilburn. (*I.E.E., Measurements Section, Paper No. 1164.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 99, No. 68, April, 1952, pp. 107–120, Discussion, pp. 120–123, illus. 13 references.

Construction, principles of operation, and application of computing circuits for electronic high-speed digital computers that use serial representation of binary numbers, developed for the University of Manchester digital computer.

High Stability Computer Reference Power Supply. Frank R. Bradley and Rawley D. McCoy. *Tele-Tech*, Vol. 11, No. 5, June, 1952, pp. 44, 45, illus. Circuit of the high-capacity reference power supply for the Reeves REAC analog computer.

The Solution of Algebraic Equations on the EDSAC. R. A. Brooker. *Cambridge Philosophical Society, Proceedings*, Vol. 48, Part 2, April, 1952, pp. 255–270, illus. 16 references.

Analysis of three iterative methods for solving algebraic equations on the EDSAC high-speed digital computer to determine the suitability of these methods as routines for high-speed computers.

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Multiple Scattering of Radiation by an Arbitary Planar Configuration of Parallel Cylinders and by Two Parallel Cylinders. Victor Twersky. *Journal of Applied Physics*, Vol. 23, No. 4, April, 1952, pp. 407–414, illus. 4 references.

Extension of a formal solution for the scattering of a plane wave by an arbitrary configuration of parallel cylinders to the case where all the axes lie in the same plane. The scattered wave is expressed as an infinite sum of orders of scattering, the first order being the usual single scattering approximaton.

Reliable VHF Signals up to 1,250 Miles Distance. *Electronics*, Vol. 25, No. 6, June, 1952, pp. 102, 103, illus. 4 references. Results of an experiment in which a new type of *E*-layer propagation was discovered which transmits weak but consistent signals at 49.8 mc. over a 775-mile test path.

Equipment

ELECTRIC (16)

Exciter Polarity Reversals in Aircraft Alternators. R. P. Judkins and H. M. McConnell. *Electrical Engineering*, Vol. 71, No. 6, June, 1952, p. 512, illus.

Analysis of an aircraft alternator and regulator system that consists of a synchronous alternator with a built-in exciter, a carbon-pile voltage-regulator, and feedback stabilizing elements to determine the design features that contribute to exciter reversals and to suggest design changes to eliminate exciter reversibility.

Environment-Free Alternator. Dwain Fritz. *Aero Digest*, Vol. 64, No. 6, June, 1952, pp. 82, 84, illus.

Components, assembly, and performance of the G75 water-vaporization cooled, environment-free alternator, developed by Jack & Heintz, Inc., for high-altitude applications.

Braking Devices for 400-Cycle Motors. L. A. Zahorsky. *Electrical Engineering*, Vol. 71, No. 6, June, 1952, pp. 506–511, illus.

Survey of stopping devices for 400-cycle a.c. motors; factors in the proper selection of a stopping device; design and performance data on a four-pole, 2-in. diameter brake for aircraft uses.

Fault Characteristics of Aircraft Electric Systems. L. R. Larson. *Electrical Engineering*, Vol. 71, No. 6, June, 1952, pp. 543–547, illus.

HYDRAULIC & PNEUMATIC (20)

Basic Design of Hydraulic Flow Regulators. H. G. Conway. *Machine Design*, Vol. 24, No. 6, June, 1952, pp. 131–135, illus.

High-Pressure Midget. *Flight*, Vol. 61, No. 2265, June 20, 1952, p. 751, illus.

Construction and performance of a three-stage air-cooled compressor with overall dimensions of 6- by 7- by 8-in. which weighs 10 lbs. and has an output of 1.4 cu.ft. per min. at 3,000 lbs. per sq. in. when running at its normal speed of 1,500 r.p.m., developed by the Hymatic Engineering Co., Ltd., for use in aircraft high-pressure pneumatic systems.

Power Operated Controls. C. R. Down. *Shell Aviation News*, No. 167, May, 1952, pp. 14–16, illus.

A brief analysis of power-assisted and fully power-operated flying controls for high performance aircraft; detailed examination of the principal types of hydraulic transmission for use with these controls.

Air Does Hairline Job in Turbine Drive. Scott H. Reiniger. *Aviation Week*, Vol. 56, No. 25, June 23, 1952, pp. 64, 67, 68, illus.

Construction and operation of the TP 15-2 Air Turbine Drive, developed by the Stratos Div., Fairchild Engine and Airplane Corp., in which air-operated controls keep the steady state speed of the drive within one-fourth of one per cent or less of that specified.

Flight Safety & Rescue (15)

A Self-Releasing Seat-Belt. *Flight*, Vol. 61, No. 2266, June 27, 1952, p. 767, illus. Design and operation of an automatic-release device that unfastens a passenger seat belt under an excess g-load.

Flight Testing (13)

The Research Airplane. Walter T. Bonney. *Pegasus*, Vol. 18, No. 6, June, 1952, pp. 1–15, illus.

Review of U.S. projects on exploring the transonic speed range; aircraft types and air-borne and ground instrumentation for obtaining flight-test data; piloting and flight-test techniques with the Bell X-1 and the Douglas D-558-II research aircraft.

Readers' Forum: End Correction for Flight-Tested Frequency Response Obtained by Laplace Transformation. G. M. Andrew. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 569, 570, illus. 3 references.

Fuels & Lubricants (12)

Control of Lead Fouling in Aero-Engines. A. R. Griffin. *Shell Aviation News*, No. 165, March, 1952, pp. 17–21, illus. British aircraft-engine experience with tricresyl phosphate as a fuel additive.

Flame Propagation in Cylindrical Tubes. Philip Levine. *Mechanical Engineering*, Vol. 74, No. 6, June, 1952, pp. 483–485, illus. 5 references. Equipment, procedure, and results of an experimental study of the factors influencing the flame characteristics of a propane-air fuel mixture in cylindrical tubes.

Gliders (35)

Prone Flying. Fritz von Hermann. (*Thermik*, Vol. 5, Nos. 1–3, January–March, 1952.) *Sailplane and Glider*, Vol. 20, No. 6, June, 1952, pp. 5–7, illus. Brief résumé of the development of the concept of prone flying and of pilots' experiences with prone flying in German sailplanes.

Bremen-Land Two-Place All-Metal Sailplane, Germany. *Aviation Week*, Vol. 56, No. 24, June 16, 1952, p. 41, illus. Specifications and performance of the Bremen-Land American-designed, vee-tailed, aluminum alloy sailplane that is in limited production by Ernest Nipp and Co. in Germany.

Spatz Single-Place High-Wing Fabric-Covered Sailplane, Germany. *Sailplane and Glider*, Vol. 20, No. 6, June, 1952, p. 14, illus.

SZD-8 Jaskólka Mid-Wing Single-Place and SZD-9 Bocian Mid-Wing Two-Place Sailplanes, Poland. *Sailplane and Glider*, Vol. 20, No. 6, June, 1952, pp. 15, 17.

Instruments (9)

Liquid Sensing Device with No Moving Parts. Dell Phillips. *Product Engineering*, Vol. 23, No. 6, June, 1952, pp. 134, 135, illus.

Theory and design of a liquid-sensing device that is based on the principles of optics and employs photovoltaic cells to actuate indicator mechanisms; operation of an optical device that detects the presence or absence of fuel in an aircraft fuel line.

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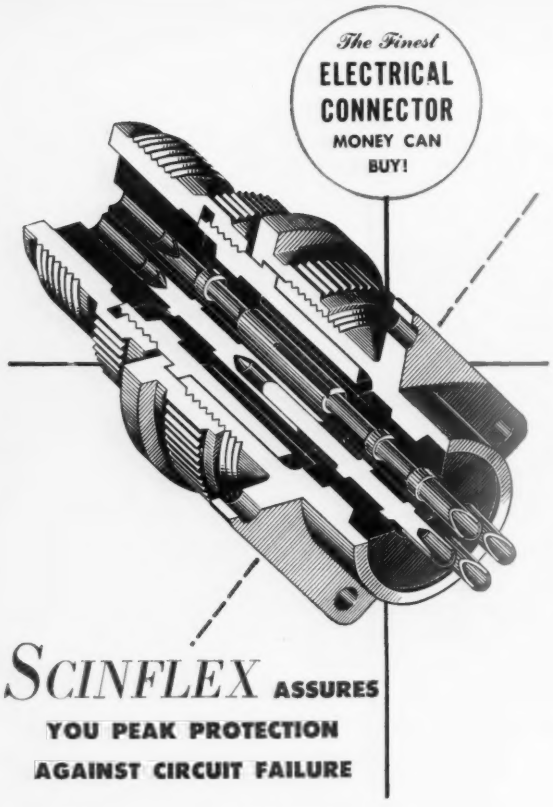

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Digital Recording and Analysing of Flight Test Data: A Proposed System. E. J. Petherick. *Gt. Brit., Aeronautical Research Council, Current Papers No. 75*, 1952 (November, 1950). 10 pp., illus. 2 references. British Information Services, New York. $0.50.

Layout, components, and operation of a small digital recorder that can punch 10,000 instrument readings on 100 ft. of cine film, each item to three decimal or twelve binary places, and which can handle any number of instruments at 10 readings per sec.; details of a unit for reading the tape and correcting errors.

Tape Recording for Telemetry & Data Analysis. I, II. Kenneth B. Boothe. *Tele-Tech*, Vol. 11, Nos. 4, 5, May, June, 1952, pp. 44–46, 116; 56, 57, 90, 92, 94, illus.

Multitrack tapes for applications in studies of guided missiles, aircraft operation, shock and vibration tests, and computers; basic design features of the tape-recording apparatus; flutter compensation; recorders that meet JAN specifications; preservation of wave shapes.

A High-Speed Recording Oscillograph. I. S. Blumenthal and A. R. Eckels. *Electrical Engineering*, Vol. 71, No. 5, May, 1952, pp. 440–445, illus. 7 references.

Construction, operation, and performance of the Oscilloscribe, a high-speed servomechanism, the basic element of which is a D'Arsonval meter movement with no restoring spring. The instrument makes ink records on a fast-moving chart of voltages with frequency components ranging from d.c. to 200 cycles per sec.

Dynamic Hysteresis Loop Measuring Equipment. H. W. Lord. *Electrical Engineering*, Vol. 71, No. 6, June, 1952, pp. 518–521, illus.

Circuit and operation of a system used to display the dynamic hysteresis loop of the core material of a magnetic amplifier on the screen of a cathode-ray oscilloscope; sources of error in the system and their effects on the display; criteria for maximum allowable error; characteristics of magnetic amplifiers of minimum performance.

Cockpit Instrument Panel Standardized. M. G. Beard. *SAE Journal*, Vol. 60, No. 6, June, 1952, pp. 50, 51, illus. Standard layouts for cockpit instrument panels, as developed by the SAE Cockpit Standardization Committee S-7.

A System Utilizing Coarse and Fine Position-Measuring Elements Simultaneously in Remote-Position-Control Servo Mechanisms. J. C. West. (*I.E.E., Measurements Section, Paper No. 1185.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 99, No. 68, April, 1952, pp. 135–143, illus. 9 references.

Development of a system that can simultaneously use the coarse and fine position-measuring elements normally employed in a high-precision position-control servomechanism without switching from coarse to fine. Final accuracy is that of fine measuring devices alone.

Nomograms Simplify Analysis of Servomechanisms. R. Hadekel. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 165–169, illus.

Operating principles of servomechanisms; development of a method of graphic analysis for such mechanisms which uses two nomograms, one for determining system amplification from loop gain and loop phase angle, the other for determining system phase angle from loop gain and loop phase angle.

A Wide-Range A-C Bridge Test for Magnetic Materials. D. C. Dieterly and C. E. Ward. *American Society for Testing Materials, Bulletin*, No. 182, May, 1952, pp. 75–80, illus. 2 references.

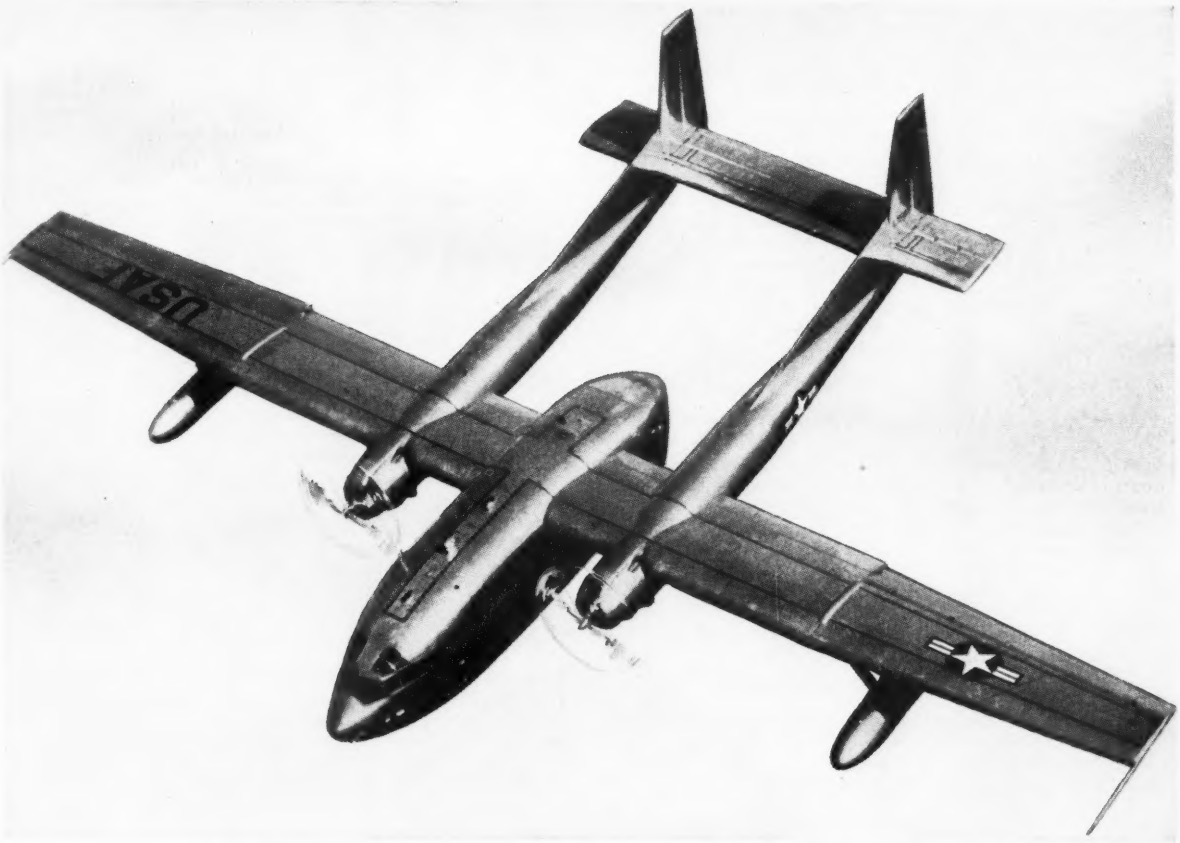
Application of a modified Hay resonance bridge circuit to determining the magnetic properties of core materials in a form suitable for estimating design performance; balance equations and circuit diagrams of the modified Hay bridge; accuracy.

Bismuth Thermocouples. Alvin B. Kaufman. *Instruments*, Vol. 25, No. 6, June, 1952, pp. 762, 802, 803, illus.

Properties of ductile bismuth and bismuth alloy "B" wire; application to thermocouples suitable for temperature measurement in the subzero range; thermocouple design and construction.

Circular Sweep Chronograph for Single Millisecond Time Intervals. Arthur Linz, Jr. *Review of Scientific Instruments*, Vol. 23, No. 5, May, 1952, pp. 199–203, illus. 3 references.

Circuits, components, and operation of a chronograph for measuring time invervals up to 1,000 μsec. with an accuracy of ±10 mμsec., for use in ballistics research. The system consists



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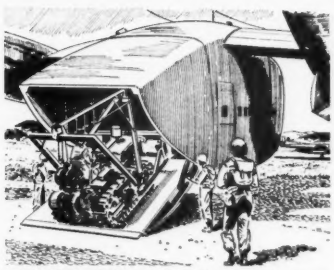

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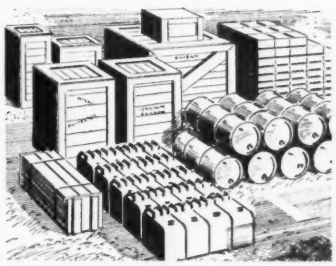

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Machine Elements (14)

BEARINGS

American Standard Tolerances for Ball and Roller Bearings. V. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 65, 66, illus.

Snap ring and groove dimensions; ball and roller dimensions and tolerances; hardness measurements; table of tolerances, in inches, of airframe bearings; tolerances of thrust ball bearings.

Discussion on "The Calculated Performance of Dynamically Loaded Sleeve Bearings—III." by J. T. Burwell. G. B. Du Bois, B. L. Newkirk, F. W. Ocvirk, and E. M. Simons. **Author's Reply.** *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 239–241, illus. 4 references.

FASTENINGS

High Temperature Fastening Problem Solved with Special Self-Locking Nuts. Charles F. Faroni. *Materials & Methods*, Vol. 35, No. 6, June, 1952, pp. 109–111, illus. Materials selection and design features of self-locking fasteners that can withstand vibration at temperatures up to 1,200°F.

Nitrile Rubber Gaskets Make Better Seals. T. C. Aitchison and B. N. Bowers. *General Electric Review*, Vol. 55, No. 3, May, 1952, pp. 46–50, illus.

Characteristics and application of gaskets made of nitrile rubber, a synthetic compound; advantages over other gasket materials; 16 illustrations of uses of gaskets made of No. 1000 compound and of nitrile rubber.

Metal Stitching. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 151–153, illus.

Equipment and techniques used in metal stitching for joining thin-section metals and nonmetals at high production rates; applications; comparison with conventional joining methods; recommended material thicknesses for stitching.

GEARS & CAMS

Noncircular Cams and Gears for Transmitting Motion at a Continuously Varying Velocity Ratio. A. E. Lockenvitz, J. B. Oliphint, W. C. Wilde, and James M. Young. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 141–145, illus.

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Radii of Curvature in Slider-Crank Mechanisms. Jesse Huckert. *Product Engineering*, Vol. 23, No. 6, June, 1952, pp. 126–133, illus.

Development of a semigraphic method for determining the radii of curvature of the locus of any particle in any link of a slider-crank mechanism, including the inversions; charts of angular magnitudes for mechanisms of several ratios.

Analyzing Accelerations of Complex Mechanisms. R. T. Hinkle. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 159–161, illus. 2 references.

Development of a method of acceleration analysis in which conventional polygon methods are applied to mechanisms containing more than one floating link.

Calculating Speed of Snap-Action Mechansims. P. H. Winter. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 162–164, illus.

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Designing Leaf Springs. George V. Nolde. *Machine Design*, Vol. 24, No. 6, June, 1952, pp. 125–130, illus. 7 references. Design factors and computation of the dynamics of a system involving flexible leaf springs for precision timing and indexing devices.

How to Choose Spring Materials. II. M. Gerard Fangemann. *Materials & Methods*, Vol. 35, No. 5, May, 1952, pp. 112–116, illus.

Analysis of the relationship between the cost and performance of a spring and the spring material; tables of the mechanical, physical, and chemical properties of spring materials.

Maintenance (25)

Douglas Service, Vol. 10, No. 3, May-June, 1952. 20 pp., illus. DC-3S, -4, -6.

Inflatable Jet Pod Maintenance Shelter. *Shell Aviation News*, No. 165, March, 1952, p. 11, illus.

Construction of a lightweight inflatable jet pod shelter developed by the Goodyear Tire and Rubber Co. for the U.S.A.F. to facilitate maintenance of the engines of the B-36 bomber aircraft in adverse weather conditions at remote airfields.

Overhaul Period for Bristol Hercules Extended to 1200 Hours. *Shell Aviation News*, No. 167, May, 1952, p. 17, illus.

Construction and test methods used on a Bristol Hercules 634 engine installed in a Vickers-Armstrongs Viking aircraft, the interoverhaul period of which has been extended to 1,200 hours with the approval of the Air Registration Board.

Materials (8)

Stretching Valve Vitality. Warren Walker, Jr. *Instrumentation*, Vol. 6, No. 1, 2nd Quarter, 1952, p. 36, illus.

Facilities and equipment at Eaton Manufacturing Co. for measuring the high-temperature strength of materials for engine valves, and for selecting substitute (noncritical) materials for reciprocating- and jet-engine parts.

A Wide-Range A-C Bridge Test for Magnetic Materials. D. C. Dieterly and C. E. Ward. *American Society for Testing Materials, Bulletin*, No. 182, May, 1952, pp. 75–80, illus. 2 references.

Application of a modified Hay resonance bridge circuit to determining the magnetic properties of core materials in a form suitable for estimating design performance.

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Some Applications of Ferroxcube. W. Six. *Philips Technical Review*, Vol. 13, No. 11, May, 1952, pp. 301–311, illus. 7 references. Review of the applications of Ferroxcube, a range of ceramic ferromagnetic materials of high volume resistivity.

Ceramic Coatings. John V. Long. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 122–126, illus.

Advantages of and design techniques for use with ceramic coatings for extending the service life of currently used heat-resistant alloys and for permitting the substitution of alloys with less critical material content; development and test results of Solar Aircraft Co.'s Solaramic process and Solar coatings, capable of withstanding 1,600°F., for mild-steel jet-engine combustion chamber liners.

New Developments in Porcelain and Ceramic Coatings. Philip O'Keefe. *Materials & Methods*, Vol. 35, No. 5, May, 1952, pp. 87–89, illus. Development of one-coat enamels, improved enamelling stock, and coatings with improved abrasion and impact properties; applications.

Ceramics for Jet Use Put into Production. *Aviation Week*, Vol. 56, No. 23, June 9, 1952, pp. 30, 32, 35, 36, illus.

Production technique and routine for applying high-temperature ceramic coatings, developed by the Bettinger Corp., to prolong the life of metals and to permit the use of lower grade metals at high temperatures.

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Migration of Cobalt During Firing of Ground-Coat Enamels on Iron. William N. Harrison, Joseph C. Richmond, Joseph W. Pitts, and Stanley Benner. *U.S., N.A.C.A., Technical Note No. 2695*, June, 1952. 28 pp., illus. 15 references.

CORROSION & PROTECTIVE COATINGS

Aluminized Coatings. M. G. Whitfield and V. Sheshunoff. *Machine Design*, Vol. 24, No. 5, May, 1952, pp. 139, 140, illus. 4 references. The properties and advantages of aluminum coatings and methods of aluminizing cast iron and steel to protect against heat and corrosion.

Materials & Methods Manual No. 83: Electroplated Coatings on the Light Metals. Philip O'Keefe. *Materials & Methods*, Vol. 35, No. 6, June, 1952, pp. 119–130, illus. Surface preparation and processes for electroplating aluminum, magnesium, and titanium; properties of the electrodeposits; applications.

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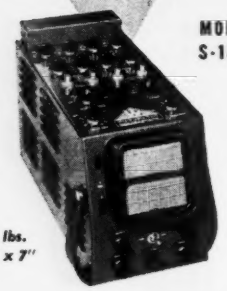

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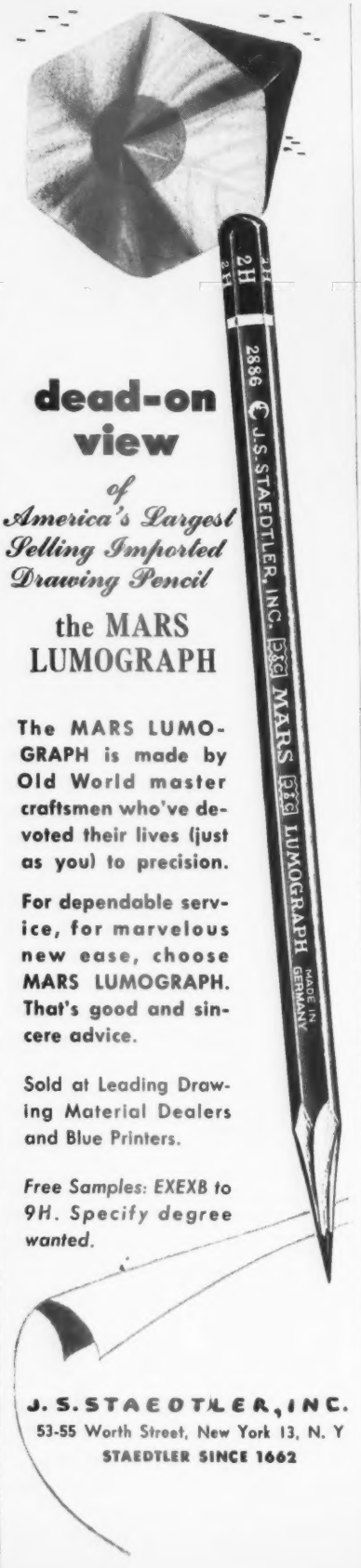

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METALS & ALLOYS

European Research on the Behavior of Metals Yields Promising Results. Thomas J. Dolan. *Materials & Methods*, Vol. 35, No. 6, June, 1952, pp. 93–96, illus. Summary of European progress in fatigue testing and stress analysis of metals.

Fatigue of Aircraft Materials with Special Reference to Micro-Structure. P. L. Teed. *Royal Aeronautical Society, Journal*, Vol. 56, No. 498, June, 1952, pp. 427–437, illus. 1 reference. The mechanism of the fatigue of ductile metals by the imposition of cyclic stresses.

Some Fatigue Tests on Aluminum-Alloy and Mild-Steel Sheet, with and Without Drilled Holes. C. E. Phillips and A. J. Fenner. *Institution of Mechanical Engineers, Proceedings, Vol. 165, War Emergency Proceedings No. 65, Applied Mechanics*, 1951, pp. 125–129, Discussion, pp. 130–140, illus. 14 references.

Results of fatigue tests, under pulsating direct stress, of panels about 0.1 in. thick and up to 12 in. wide of a 14-gage D.T.D. 646B aluminum alloy and a 12-gage commercial mild black steel sheet, with and without central holes; comparison with results of tests on panels of similar shapes but of different sizes.

Selecting Metals for Low Temperature Service. J. R. Watt. *Product Engineering*, Vol. 23, No. 6, June, 1952, pp. 158–161, illus. Factors that affect the behavior of metals at subzero temperatures.

Welding Characteristics of Materials for Aircraft Gas Turbines. A. J. Rosenberg. *Welding Journal*, Vol. 31, No. 5, May, 1952, pp. 407–413, illus.

Results of research undertaken by General Electric Co. on the welding characteristics of sheet metals for jet engine applications which included austenitic stainless steels, Inconel, Haynes Stellite alloys, low-alloy high-tensile steels (for applications in temperatures up to 800°F.), and titanium and titanium alloys.

Influence of Structure on Properties of Sintered Chromium Carbide. H. J. Hamjian and W. G. Lidman. *U.S., N.A.C.A., Technical Note No. 2731*, June, 1952. 21 pp., illus. 3 references.

Alloy Conservation in Valve Materials. II—Special Heat and Corrosion Resisting Alloys. L. J. Danis. *Eaton Engineering Forum*, Vol. 13, No. 3, May, 1952, pp. 1–5. 2 references.

An analysis of the problems in the reduction of critical alloy content in heat- and corrosion-resistant steels used in engine exhaust valves; tables give a type analysis of martensitic, austenitic, and precipitation-hardening valve steels and of valve seat facings.

A Fundamental Study of the Mechanism by Which Hydrogen Enters Metals During Chemical and Electrochemical Processing. L. D. McGraw, C. A. Snavely, H. L. Moore, P. T. Woodberry, and C. L. Faust. *U.S., N.A.C.A., Technical Note No. 2696*, April, 1952. 40 pp., illus. 15 references.

Theory and experimental data that led to an explanation of the mechanism of the process by which hydrogen enters and leaves metals. Known methods of controlling the entry and exit of hydrogen in steel were correlated with the chemical behavior of atomic and molecular hydrogen, as the basis for this explanation.

Magnetic Properties of Ferrite Materials. Ephraim Gelbard. *Tele-Tech*, Vol. 11, No. 4, May, 1952, pp. 50–52, 82, 84, illus. Types of Ferramic materials; tabulation of their magnetic properties; applications.

Precipitation Hardening Stainless Steels Show Advantages Over Standard Grades. Gordon T. Bedford. *Materials & Methods*, Vol. 35, No. 5, May, 1952, pp. 99–104, illus.

Composition and properties of 17-7 PH and 17-4 PH steels; techniques of cold- and hot-working, welding, and heat-treating that develop strength in these steels equal to that of the carbon and low alloy steels at room temperature.

How to Case Harden Steel by Nitriding. John L. Everhart. *Materials & Methods*, Vol. 35, No. 5, May, 1952, pp. 90–93, illus. 10 references.

Plastic Deformation; Effect of Chromium Plating on Steel. *Aircraft Production*, Vol. 14, No. 164, June, 1952, p. 218, illus.

Repeated Load Tests on Welded and Prestrained Steels. Sadun S. Tör, Jan M. Ruzek, and Robert D. Stout. *Welding Research*, Vol. 31, No. 5, May, 1952, Supplement, pp. 238-s–246-s, illus.

Materials Engineering File Facts No. 228: Relative Workability of Representative Stainless Steels. *Materials & Methods*, Vol. 35, No. 6, June, 1952, p. 135. Table of the workability factors of six austenitic, one martensitic, and two ferritic steels.

The Size Effect in Fatigue of Plain and Notched Steel Specimens Loaded Under Reversed Direct Stress. C. E. Phillips and R. B. Heywood. *Institution of Mechanical Engineers, Proceedings, Vol. 165, War Emergency Proceedings No. 65, Applied Mechanics*, 1951, pp. 113–124, illus. 8 references.

Equipment, procedure, and results of tests of the fatigue strength under reversed direct stress for notched or plain specimens of a 25-ton mild steel and a 65-ton, $2^1/_2$ per cent nickel chromium steel.

The Effect of Quench-Aging on the Notch Sensitivity of Steel. J. R. Low, Jr. *Welding Research*, Vol. 31, No. 5, May, 1952, Supplement, pp. 253-s–256-s, illus. 7 references.

Influence of Nitrogen on the Notch Toughness of Heat-Treated 0.3-percent-Carbon Steels at Low Temperatures. Glenn W. Geil, Nesbit L. Carwile, and Thomas G. Digges. *U.S., National Bureau of Standards, Journal of Research*, Vol. 48, No. 3, March, 1952, pp. 193–199, illus. 38 references. (Also available as *Research Paper No. 2305*. Superintendent of Documents, Washington. $0.10.)

Bismuth Thermocouples. Alvin B. Kaufman. *Instruments*, Vol. 25, No. 6, June, 1952, pp. 762, 802, 803, illus. Properties of ductile bismuth and bismuth alloy "B" wire; application to thermocouples suitable for temperature measurement in the subzero range.

Thermal Expansion of Aluminum and Some Aluminum Alloys. Peter Hidnert and H. S. Krider. *U.S., National Bureau of Standards, Journal of Research*, Vol. 48, No. 3, March, 1952, pp. 209–220, illus. 16 references. (Also available as *Research Paper No. 2308*. Superintendent of Documents, Washington. $0.10.)

Coefficients of expansion obtained during heating and cooling of samples of aluminum and of some aluminum alloys for various temperature ranges between −50° and +400°C. Correlations are established between the coefficients of expansion and the chemical composition of the annealed aluminum alloys.

The Anodic Oxidation of Aluminium. G. C. Thompson. *Electronic Engineering*, Vol. 24, No. 292, June, 1952, pp. 281–283. Theory of anodizing; explanation of and comparison of the chromic acid and sulphuric acid anodizing processes.

New Aluminum-Plating Process. *U.S., National Bureau of Standards, Technical News Bulletin*, Vol. 36, No. 6, June, 1952, pp. 86, 87, illus. 1 reference.

Plating techniques and equipment and evaluation of a process for electrodepositing aluminum at room temperature which uses an organic plating bath consisting of an ether solution of aluminum chloride and a metal hydride.

Strength Properties of Welds in 61S-T6 Aluminum Alloy Sheet. Louis Barrett. *Product Engineering*, Vol. 23, No. 6, June, 1952, pp. 148–150, illus.

Analysis of the tensile strength of butt joints and shear strength of lap joints in aluminum alloy sheet as obtained with the inert gas welding process where the filler wire is used for the electrode.

Good Aluminum Welding Starts with the Engineer. R. M. Curran. *General Electric Review*, Vol. 55, No. 3, May, 1952, pp. 13–15, illus.

Engineering design considerations in the selection of aluminum alloys for various welding process; tables of melting ranges of some common aluminum alloys and for the applicability of welding processes for wrought aluminum alloys.

Aluminium and Magnesium Alloys. G. Meikle. *Society of Licensed Aircraft Engineers, Journal*, Vol. 1, No. 4, April, 1952 (*Technical Instructor*, Vol. 7, No. 4), pp. 8–13, Discussion, pp. 13, 14, 18, illus., tables.

Effect of Open Circular Holes on Tensile Strength and Elongation of Sheet Specimens of a Magnesium Alloy. R. S. Barker. *U.S., N.A.C.A., Technical Note No. 2716*, June, 1952. 24 pp., illus. 10 references.

Forming Tools for Magnesium Alloys. John Starr. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 69, 70, illus.

Materials & Methods Manual No. 82: Titanium and Its Alloys. John L. Everhart. *Materials & Methods*, Vol. 35, No. 5, May, 1952, pp. 118–132, illus. Engineering properties; forming and machining characteristics; cleaning and finishing; heat treatment; weldability; present and future uses.

What We Know About Titanium. P. G. DeHuff and W. S. Hazelton. *Aviation Week*, Vol. 56, No. 22, June 2, 1952, pp. 40, 41, 44–46, illus. Factors in the selection of tools, coolants, and techniques of forging, joining, and machining in the production of titanium components.

Titanium. *Flight*, Vol. 61, No. 2266, June 27, 1952, pp. 768–770, illus. Properties, applications, advantages, and disadvantages of titanium for aircraft component construction.

The Cost of Titanium-Alloy Advantages. *Aviation Week*, Vol. 56, No. 26, June 30, 1952, pp. 21, 22, 24–26, 29, 32, illus. Properties of titanium and research and production techniques for the application of various titanium alloys to aircraft jet- and piston-engine components.

NONMETALLIC MATERIALS

Effect of Temperatures from −70° to 600°F. on Strength of Adhesive-Bonded Lap Shear Specimens of Clad 24S-T3 Aluminum Alloy and of Cotton- and Glass-Fabric Plastic Laminates. H. W. Eickner, W. Z. Olson, and R. F. Blomquist. *U.S., N.A.C.A., Technical Note No. 2717*, June, 1952. 26 pp., illus.

Evaluation of the performance of 14 commercial adhesives used in bonding clad 24S-T3 aluminum alloy to itself, and of seven commercial adhesives used in lap joints of cotton-fabric-phenolic laminate to itself, of glass-fabric-polyester laminate to itself, and in joints of each of these laminates to clad aluminum.

New Potting Compound Has Controlled Shrinkage. *Materials & Methods*, Vol. 35, No. 6, June, 1952, pp. 117, 118, illus.

General characteristics and properties and applications of Polyform, a series of polyester-type compounds developed by B. G. Forman Co., New York, for potting, encapsulating, sealing, embedding, and impregnating electric and electronic components.

Plastic Aircraft Development. W. F. Bradley. *Automotive Industries*, Vol. 106, No. 11, June 1, 1952, pp. 48, 49, 88, illus.

Techniques developed by the Royal Aircraft Establishment for molding and constructing delta-shaped wings from Durestos, a plastic sheet material that consists of asbestos fibers bonded by a phenol-formaldehyde resin.

ASTM Definitions of Terms Relating to Methods of Testing. *American Society for Testing Materials, Bulletin*, No. 182, May, 1952, pp. 66–70. Proposed definitions of terms and symbols relating to the tension testing of plastics.

Silastic Facts. *Dow Corning Corp., Reference No. 10a*, May, 1952. 16 pp., illus., tables.

Chemical composition, properties, and limitations of Silastic; basic data on the properties and behavior of all types of Silastic now commercially available; dielectric behavior; charts and tables of the properties of Silastic at high and low extremes of temperature; resistance to weather, chemicals, and oil.

Nitrile Rubber Gaskets Make Better Seals. T. C. Aitchison and B. N. Bowers. *General Electric Review*, Vol. 55, No. 3, May, 1952, pp. 46–50, illus. Development and characteristics of nitrile rubber, a synthetic compound; application to the manufacture of gaskets.

Apparatus for the Measurement of the Dynamic Shear Modulus and Hysteresis of Rubber at Low Frequencies. W. P. Fletcher and A. N. Gent. *Journal of Scientific Instruments*, Vol. 29, No. 6, June, 1952, pp. 186–188, illus. 6 references.

SANDWICH MATERIALS

Stainless-Clad Copper. *Machine Design*, Vol. 24, No. 6, June, 1952, pp. 141, 142, illus.

Thermal properties and test data of a composite sheet material composed of a copper core clad with stainless steel, developed by American Cladmetals Co. The sandwich material is suitable for jet-engine combustion chambers, exhaust headers, afterburner vanes, and other high-temperature applications.

Use of a Low-Density Core Material in Aircraft Structures. Raymond J. Moore and John M. Ellison. *Aeronatical Engineering Review*, Vol. 11, No. 9, September, 1952, pp. 52–54, illus.

Test results, economic, weight, and mechanical advantages, and comparison with all-metal structures of airframe components fabricated of a Styrofoam (foamed polystyrene) core bonded to thin aluminum-sheet skins.

Meteorology (30)

Activities of the Geophysics Research Division, Air Force Cambridge Research Center (AFCRC). H. E. Landsberg. *Weatherwise*, Vol. 5, No. 3, June, 1952, pp. 55–58, illus.

A Meteorological Analysis of Reports of Turbulence Encountered by Aircraft in Clear Air. Conrad P. Mook. *Aeronautical*

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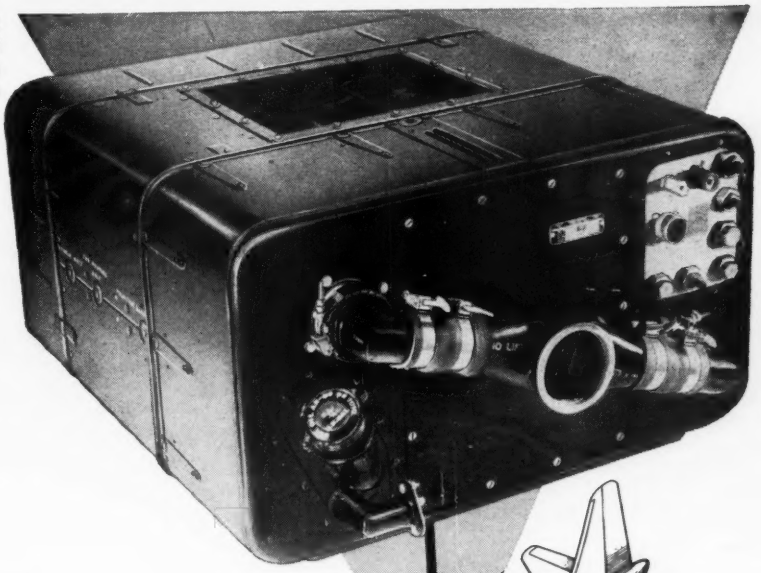

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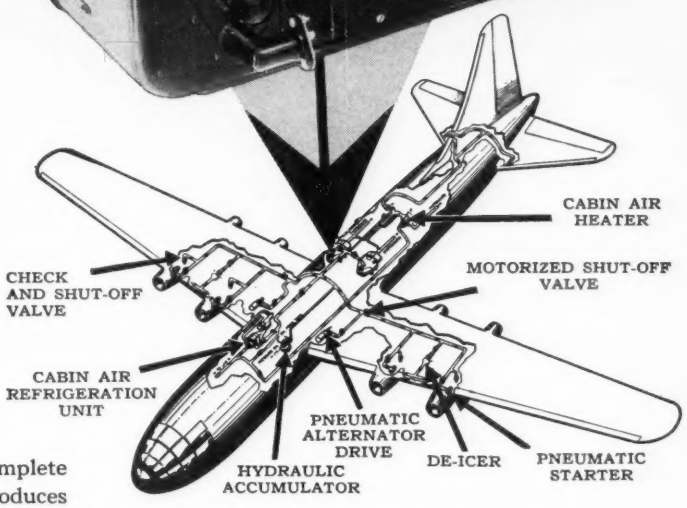

This vital unit, weighing about 150 pounds, complete in a chromium-nickel stainless steel case, produces from 50 to 100 compressed air horsepower...

It supplies the compressed air through ducts to air turbine starters and other auxiliary air or gas turbine motors...spinning the turbines at high speed.

These turbines, in turn, power starters and other accessories through nickel alloyed steel reduction gears.

Speed reduction in air turbine starters, for example, is from 84,000 to 3,650 r.p.m. To assure maximum gear life under such severe operation, nickel-containing steels SAE 3310 (AMS 6250) and SAE 9310 are specified by the manufacturer... AiResearch Manufacturing Company of Los Angeles... a firm which specializes in developing and producing aircraft accessory equipment.

AMS 6250, a nickel alloyed steel, long recognized as the ultimate in carburizing steels, completely meets the demands imposed by heavy loads on mating surfaces of gear teeth. Probably the most dramatic use of a nickel alloy is that of Inconel "X", a 70% nickel-chromium "super alloy" adopted after tests for the turbine "hot wheel"... which operates at top peripheral speeds of 40,000 r.p.m. at temperatures up to 1600°F. Applications like these attest to the remarkable combination of properties available in alloys containing nickel.

ADVANTAGES OF GAS TURBINE POWER SYSTEM

1. Permits unlimited number of consecutive starts, dependent only on fuel supply carried for main power plants.
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Engineering Review, Vol. 11, No. 9, September, 1952, pp. 22–27, illus. 12 references.

Flow of Angular Momentum As a Predictor for the Zonal Westerlies. Edward N. Lorenz. *Journal of Meteorology*, Vol. 9, No. 2, April, 1952, pp. 152–157. 10 references.

A Zonal-Index Tendency Equation and Its Application to Forecasts of the Zonal Index. Yale Mintz and Shih-Kung Kao. (*California, University, Los Angeles, Dept. of Meteorology, Papers in Meteorology, No. 14.*) *Journal of Meteorology*, Vol. 9, No. 2, April, 1952, pp. 87–92, illus. 3 references.

Meteorological Measurements with Quartz Crystals. Paul Goldsmith and Edward A. Roberts. *Electronics*, Vol. 25, No. 6, June, 1952, pp. 144–147, illus. Methods of utilizing quartz crystals and associated electronic circuits to detect and measure changes in pressure, temperature, and humidity.

Wind Recorder for Microclimatology. George West. *Electronics*, Vol. 25, No. 6, June, 1952, pp. 136–138, illus. 4 references.

Circuits, construction, and operation of a climate survey system that consists of a wire-speed transducer, a wind-direction transducer, and a translator unit that drives standard recording milliammeters of the spring-activated type. A keep-alive circuit modulates the action of the recording pen with a small amplitude square wave, thus speeding pen response.

Missiles (1)

Research for Guided Missiles. *The Aeroplane*, Vol. 82, No. 2134, June 13, 1952, pp. 725–727, illus.

Development, construction, and operation of the Government Aircraft Factory, Australia Jindivik 1 pilotless jet aircraft and of its piloted version, the Pika, built to reduce its development time.

Rocket Model Does Work of Windtunnel. George L. Christian. *Aviation Week*, Vol. 56, No. 23, June 9, 1952, pp. 21, 22, 24, 25, illus.

Construction, instrumentation, and operation of a rocket-powered vehicle that carries a scale-model tailless delta-type fighter wing and telemetering equipment, and provides accurate flight information less expensively than wind-tunnel tests.

Navigation (29)

New Aircraft Pictorial Computer. *Tele-Tech*, Vol. 11, No. 5, June, 1952, pp. 66, 84, illus. Design and operation of the Arma pictorial computer.

Photography (26)

Ballistics Photography Uses Mobile Flash. Ernest C. Barkofsky. *Electronics*, Vol. 25, No. 6, June, 1952, pp. 128–130, illus. 1 reference.

Circuits, construction, and operation of mobile flash equipment to provide light flashes of μsec. duration at repetition rates up to 3,000 per sec., developed for use in daytime range tests of rockets and other supersonic projectiles.

Power Plants

JET & TURBINE (5)

Improving Turbojet Service Life. Warren R. Petersen. *Aero Digest*, Vol. 64, No. 6, June, 1952, pp. 50, 52, 54, 56–59, illus.

Outline of the metallurgical problems, particularly creep, that effect the service life of turbojet engines; design and operational factors that increase the adverse metallurgical effects; suggested solutions for these problems which include instruments for registering the total time of engine operation under critical conditions.

The Supersonic Axial Compressor. J. E. B. Perkins. *Shell Aviation News*, No. 167, May, 1952, pp. 20, 21, illus. Advantages of the axial compressor as compared with the centrifugal compressor for supersonic flight.

School Jet. *Aviation Week*, Vol. 56, No. 24, June 16, 1952, pp. 53, 54, illus. Construction and operation of the Centriflow, a 172-lb. turbojet engine of 340 lbs. thrust, developed by students at the Northrop Aeronautical Institute.

Bristol's New Proteus. *The Aeroplane*, Vol. 82, No. 2133, June 6, 1952, pp. 685–695, illus., cutaway drawings.

Specifications and performance of the Proteus 705 turboprop engine that delivers 3,320 h.p. at the propeller shaft, plus 1,200 lbs. jet thrust, a total of 3,780 equivalent h.p. at maximum compressor r.p.m., and has a specific fuel consumption of 0.71 lb. per b.h.p. per hr., developed to power the production version of the Bristol Britannia.

Details of DC-3's Auxiliary Jet. *Aviation Week*, Vol. 56, No. 22, June 2, 1952, pp. 32, 33, illus. Results of S.C.N.A.S.O. flight trials of a Douglas DC-3 fitted with an auxiliary Turboméca Palas turbojet of 310 lbs. thrust.

U.S. Buys French Portable Jet Starter. *Aviation Week*, Vol. 56, No. 24, June 16, 1952, pp. 78, 80, illus.

Construction and operation of Aubrélec, a portable ground power unit developed in France by Aubrey et Simonin, Société Électron, and Ford SAF, for starting jet aircraft engines, which is being purchased as a standard jet starter by U.S.A.F. forces in Europe.

RAM-JET & PULSE-JET

Tests on a Working Model Ram Jet in a Supersonic Wind Tunnel. J. R. Singham, F. W. Pruden, and R. C. Tomlinson. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2568*, 1951 (November, 1947). 16 pp., illus. 1 reference. British Information Services, New York. $1.15.

Mechanical and thermodynamic design details of a small scale model of a ram-jet burning hydrogen which was tested in the N.P.L. 1-ft. diameter Circular High-Speed Tunnel; experimental techniques and results. Detachable diffuser and exit sections permitted tests to be made at inlet speeds of 100 ft. per sec. with stagnation-temperature rises to 700, 850, and 1,000°C. and at 200 ft. per sec. with a temperature rise to 700°C.

RECIPROCATING (6)

Tests on a (Sulzer 2ZG9) High-Speed Two-Stroke Cycle Opposed-Piston Diesel Engine. A. I. Ibrahim Abdelfattan. (*Zurich, Eidgenössische Technische Höchschule, Dissertation No. 2053.* 31 pp.) *Engineers' Digest*, Vol. 13, No. 5, May, 1952, p. 144. 2 references.

Control of Lead Fouling in Aero-Engines. A. R. Griffin. *Shell Aviation News*, No. 165, March, 1952, pp. 17–21, illus. Results of spark-plug fouling tests on single-cylinder and main engines of British aircraft using tricresyl phosphate as a fuel additive.

Overhaul Period for Bristol Hercules Extended to 1200 Hours. *Shell Aviation News*, No. 167, May, 1952, p. 17, illus.

Construction and test methods used on a Bristol Hercules 634 engine installed in a Vickers-Armstrongs Viking aircraft, the inter-overhaul period of which has been extended to 1,200 hours with the approval of the Air Registration Board.

The Effects of Atmospheric Humidity and Temperature on Engine Power and Take-Off Performance of a (Handley Page) Hastings 1. G. Jackson. *Gt. Brit., Aeronautical Research Council, Current Papers No. 77*, 1952 (February 9, 1950). 34 pp., illus., folding charts. 10 references. British Information Services, New York. $1.40.

Flight tests to determine the effects of changes in humidity and air temperature on engine power, fuel, and take-off performance; engine specifications and limitations.

ROCKET (4)

Design of Apparatus for Determining Heat Transfer and Frictional Pressure Drop of Nitric Acid Flowing Through a Heated Tube. Bruce A. Reese and Robert W. Graham. *U.S., N.A.C.A., Research Memorandum No. 52D03*, June 16, 1952. 61 pp., illus. 18 references.

Design basis of test apparatus for obtaining the heat-transfer and pressure-drop characteristics of white fuming nitric acid flowing in a heated tube, assuming that the heat flux to the tube will be of the order of magnitude occurring in a regeneratively cooled rocket engine.

Production (36)

Canadair: Ambitious Aviation Youngster. Irving Stone. *Aviation Week*, Vol. 56, No. 24, June 16, 1952, pp. 24, 27, 28, 30, 32, 34, 36, 37, illus.

Development and facilities of Canadair, Ltd.; aircraft produced under contract or license; plans for the CL-21 32-place feederline transport aircraft to replace the DC-3.

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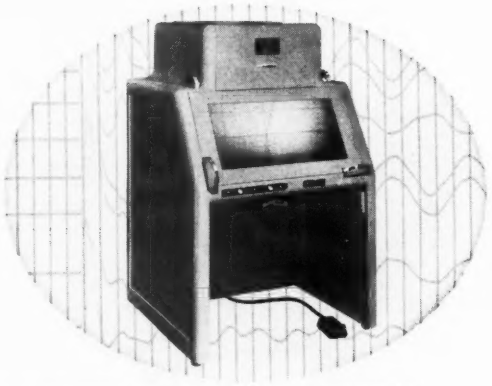

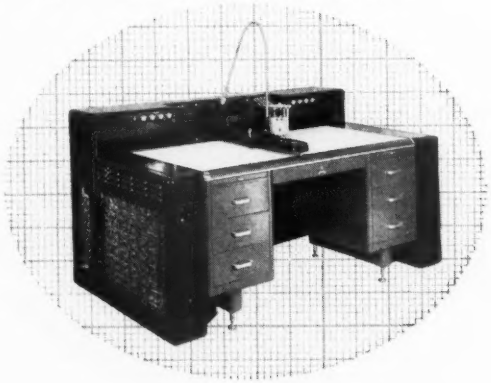

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Blades by Upsetting. *Flight*, Vol. 61, No. 2263, June 6, 1952, p. 686, illus.

Construction and operation of a series of upsetting machines developed by Omes, Ltd. of Barnes, London, which employ electric-resistance heating to produce a controlled upset at any point on bar stock; electroforging and upsetting techniques used with these machines to produce turbine rotor and stator turbine and axial compressor blades with any type of root end or shrouding in any standard blade material.

Forged Skin-Panels. I—Design Consideration; Forging Principles; Die Design. *Aircraft Production*, Vol. 14, No. 164, June, 1952, pp. 191–197, illus. Development of techniques for the production of integrally-stiffened aircraft units.

Precision Forging of Turbine Vanes, Blades, and Buckets. Joseph Geschelin. *Automotive Industries*, Vol. 106, No. 12, June 15, 1952, pp. 34, 35, 87, 88, illus.

Machines and equipment used at the Packard Motor Car Co. for the precision forging of vanes, blades, and buckets for aircraft gas-turbine power plants; steps in the forging operation.

Circular Stretching. *Aircraft Production*. Vol. 14, No. 164, June, 1952, pp. 198, 199, illus. Expanding segmental-die for sizing gas-turbine stiffener-rings.

Redesign for Fabrication. *Machine Design*, Vol. 24, No. 6, June, 1952, pp. 167, 224, illus. A new manufacturing method for stator blades of jet engines involves fabrication of the complete blade, rather than the conventional techniques of forging the blades.

Contour Milling Aircraft Skins from Rolled Aluminum Stock. Jesse Daugherty. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 47–50, illus. Machines for milling aircraft skins, including integrally-stiffened parts; milling procedures.

Duplicating Jet Engine and Compressor Blades. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 50, 51, illus.

Components and operation of an automatic abrasive belt grinder developed by Pratt & Whitney Aircraft Div. and the Minnesota Mining and Manufacturing Co. for producing compressor and turbine blades. The machine operates on the duplicating principle and uses high-speed abrasive belts for precision stock removal.

Precision Grinding of Cylindrical Parts. A. E. Mandeville and J. Meehan. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 37–39, 56, illus. Machine and tooling requirements for precision grinding; problems in alignment and taper control; steps in the grinding operation.

Survey of Modern Theory on Welding and Weldability. II. D. Séférian. *Sheet Metal Industries*, Vol. 29, No. 302, June, 1952, pp. 529–532, 540, illus. 5 references.

Welding Characteristics of Materials for Aircraft Gas Turbines. A. J. Rosenberg. *Welding Journal*, Vol. 31, No. 5, May, 1952, pp. 407–413, illus.

Results of research undertaken by General Electric Co. on the welding characteristics of sheet metals for jet-engine applications and on the welding techniques to be used with such metals.

Good Aluminum Welding Starts with the Engineer. R. M. Curran. *General Electric Review*, Vol. 55, No. 3, May, 1952, pp. 13–15, illus.

Engineering design considerations in the selection of aluminum alloys for various welding processes; tables of melting ranges of some common aluminum alloys and for the applicability of welding processes for wrought aluminum alloys.

On the Relation Between Characteristics of A. C. Welders and Stability of Welding Arc. Kohei Ando. *Japan Science Review*, Vol. 2, No. 1, April, 1951, pp. 59–62, illus. 1 reference.

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Aircraft Quality Control. Phil I. Harr. *Aero Digest*, Vol. 64, No. 6, June, 1952, pp. 86, 87, 89–92. Inspection practices and techniques used by the Quality Control department of the Fairchild Aircraft Div. on the C-119 Packet transport.

New Type Hydraulic Press for Forming Aircraft Parts. *Automotive Industries*, Vol. 106, No. 11, June 1, 1952, pp. 56, 128, illus. Construction and advantages of the Wheelon direct hydraulic press for forming sheet-metal parts, in operation at Douglas Aircraft Co., Inc.

Forming Tools for Magnesium Alloys. John Starr. *Tool Engineer*, Vol. 28, No. 6, June, 1952, pp. 69, 70, illus.

Toothless Blade Has Quite a Bite. *Aviation Week*, Vol. 56, No. 25, June 23, 1952, p. 43, illus. Applications and advantages of toothless blades for handsaws which are made of ordinary metal box strapping, as developed by Solar Aircraft Co. for cutting stainless steel.

Propellers (11)

Strain Gauge Flutter Tests on a 4-Blade Propeller with Duralumin Blades. J. Kettlewell and H. G. Ewing. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2471*, 1952 (May, 1946). 4 pp., illus. British Information Services, New York. $0.35. Procedure and results of tests to measure the vibratory stresses on a four-bladed duralumin propeller of 13 ft. 3 in. diameter, at three blade settings in the stalling region.

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The free-vibration analysis of J. Meyers is repeated applying different boundary conditions for coupled vibrations of propeller blades and crankshaft. An idealized system is employed for the case where the blade is bending and the shaft is in torsion.

Reference Works (47)

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A Bibliographical Survey of German and Japanese Experience in the Extraction of Low-Grade Non-Ferrous Ores and the Recovery of Non-Ferrous Metals and Compounds. *Gt. Brit., Dept.*

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of Scientific and Industrial Research, Technical Information and Documents Unit, Report No. RMS-3, 1952. 100 pp. British Information Services, New York. $0.90.

A bibliography of 545 references, giving report number, title, author, publication date, and a brief abstract of each report, listed under the following headings: mining, ore dressing, and statistics; smelting, refining, and recovery of base metals, production and recovery of light metals; production and recovery of titanium, manganese, and metals of the 5th and 6th groups; production and recovery of precious and rare earth metals; and production and recovery of selenium. The appendixes cover documents Unit on nonferrous ore sources, including U.S. reports on the extraction and recovery of nonferrous metals.

Wings of Defense. *Canadian Aviation*, Vol. 25, No. 6, June, 1952, pp. 39–65, 85–132, illus.

Organization of the R.C.A.F.; key personnel and their commands; training program status and goals; photographs and specifications of aircraft now in use or on order by the R.C.A.F.; naval aircraft and activities; R.C.A.F. strength.

Rotating Wing Aircraft (34)

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Helicopter Power Plant Analysis. Gas Turbines Versus Reciprocating Engines. Joseph Stuart, III. **Special Air Force Helicopter Projects.** Wayne W. Eggert. **Helicopters for the Short Haul.** J. E. Rothman. *Automotive Industries*, Vol. 106, No. 12, June 15, 1952, pp. 36, 37, 116, 118, 122, 125, 126, illus. (Excerpts from three papers presented before the American Helicopter Society, Annual Forum, 8, Washington, May 15–18, 1952).

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Sciences, General (33)

MATHEMATICS

A Graphical Analysis for Non-Linear Systems. Pei-Su Hsia. (*I.E.E., Measurements Section, Paper No. 1168.*) *Institution of Electrical Engineers, Proceedings, Part II, Power Engineering*, Vol. 99, No. 68, April, 1952, pp. 125–131, Discussion, pp. 132–134, illus. 14 references.

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A Method of Summing Infinite Series. Samuel Lubkin. *U.S., National Bureau of Standards, Journal of Research*, Vol. 48, No. 3, March, 1952, pp. 228–254, illus. 3 references. (Also available as *Research Paper No. 2310.* Superintendent of Documents, Washington. $0.20.)

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Application of the method of equivalents to the analysis of indeterminate frames, with members of uniform cross sections, fully restrained against lateral sway; review of the theory of the method of equivalents.

A Summary of Diagonal Tension. I—Methods of Analysis. II—Experimental Evidence. Paul Kuhn, James P. Petersen, and L. Ross Levin. *U.S., N.A.C.A., Technical Note Nos. 2661, 2662*, May, 1952. 131 pp.; 81 pp., illus. 54 references.

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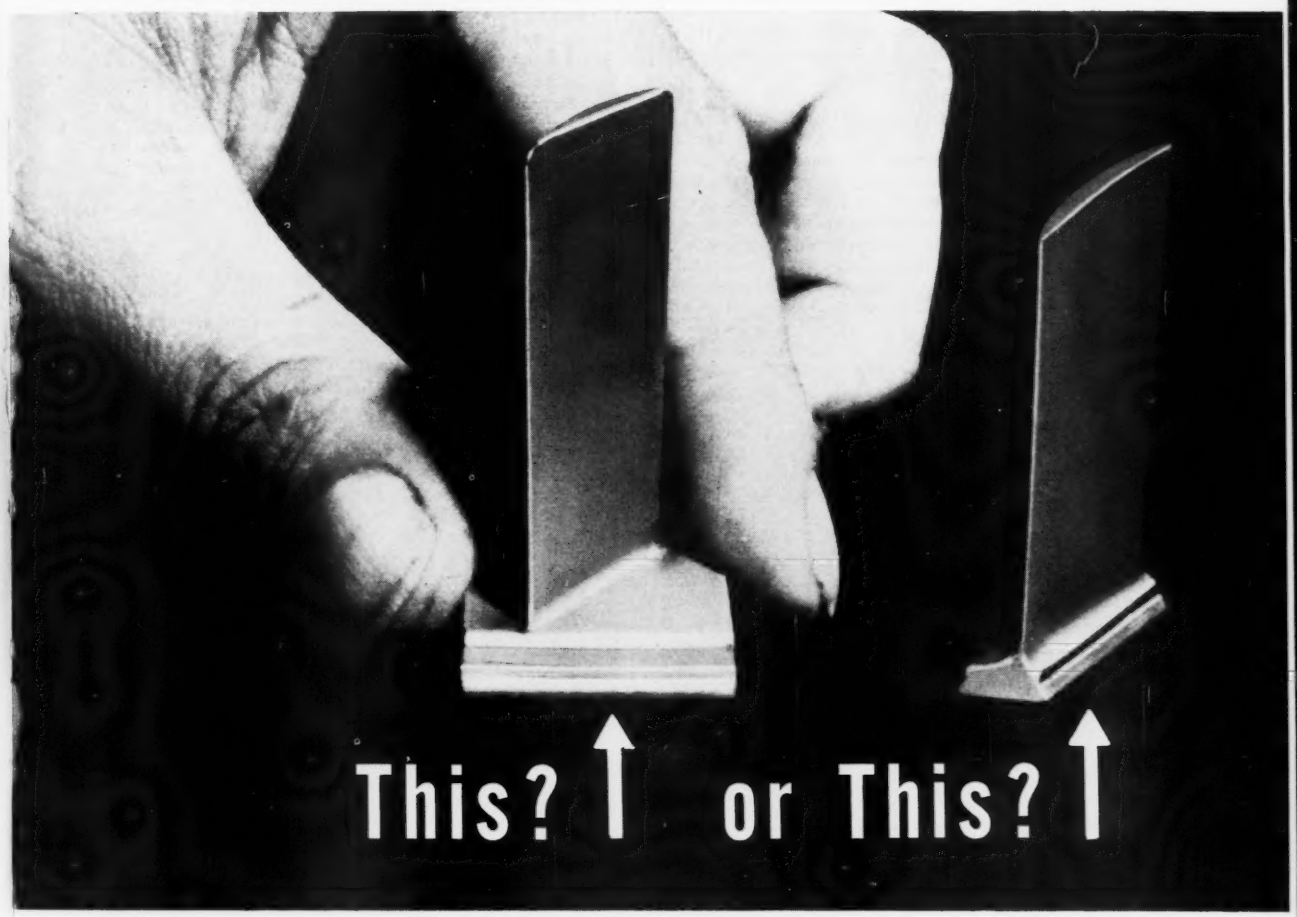
Torsional Vibration Modes of Tapered Bars. H. E. Fettis. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 220–222, illus. 2 references.

Which One Will Save a Million Dollars?



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Development of a solution for the differential equation that governs the torsional vibration modes of a cantilever shaft or bar, when these modes are simple harmonic functions of time.

Buckling of Continuous Beams on Elastic Supports. Edward Saibel. *Franklin Institute, Journal*, Vol. 253, No. 6, June, 1952, pp. 563–566, illus. 4 references.

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Readers' Forum: Lateral Buckling of Beams in Bending and Compression. F. DiMaggio, A. Gomza, W. E. Thomas, and M. G. Salvadori. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 574–576. 8 references.

Analysis of the lateral buckling of an I beam under normal loads and longitudinal thrusts, considering three cases that have linear bending-moment diagrams: a simply supported I beam under unequal end moments, simply supported, rectangular cross-section beams under unequal end moments and thrusts, and cantilever beams of rectangular cross section under thrust and shear.

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Analysis of Elastic Two and Three -Section Short Columns. C. M. Tyler, Jr., and F. Z. Lee. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 223–226, illus. 9 references. Development of analytical formulas in terms of the equivalent eccentricity of loading for two- and three-section short columns.

Load Distribution in Riveted and Spot-Welded Joints. D. Williams. (*International Congress of Applied Mechanics, 7, London*, September, 1948.) *Institution of Mechanical Engineers, Proceedings, Vol. 165, War Emergency Proceedings No. 66, Applied Mechanics*, 1951, pp. 141–147, Discussion, pp. 157–164, illus. 8 references.

Theoretical analysis, based on experimentally obtained shear-deflection curves for riveted and spot-welded joints of the load distribution for the two types of fastenings, at low loads, loads above the yield point, and of the structure load at which the yield point is reached and of the load at which failure occurs.

The Diffusion of Transverse Loads in a Reinforced Circular Cylinder with Non-Rigid Frames. S. R. Lewis. *Gt. Brit., Aeronautical Research Council, Current Papers No. 74*, 1952 (February, 1950). 22 pp., illus., folding chart. 1 reference. British Information Services, New York. $1.00. Analysis of the shear distribution around a nonrigid frame of a reinforced circular cylinder with the loaded frame at a distance away from the cylinder ends.

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Review of mathematical partially plastic thick-walled-cylinder theories; development of a simplified design theory in closed form, based on an extension of Tresca's theory to cover strain-hardening, incompressibility, and Hencky stress-strain relations.

Discussion on "On the Inextensional Theory of Deformation of a Right Circular Cylindrical Shell" by R. M. Hermes. N. J. Hoff and F. K. G. Odqvist. **Author's Reply.** *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, p. 231. 5 references.

Stress Charts for Pressurized Elliptical and Oblong Tubes. J. C. Weydert. *Product Engineering*, Vol. 23, No. 6, June, 1952, pp. 195, 197, 199, illus.

Bending and Buckling of an Elastically Restrained Circular Plate. H. Reismann. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 167–172, illus. 7 references.

Analysis, based on the classical theory of plates, of the effect of an elastic boundary restraint on the deflections, moments, and buckling loads of a circular plate; physical significance of the results.

Note on Energy of Bending of Plates. H. L. Langhaar. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, p. 228. 3 references.

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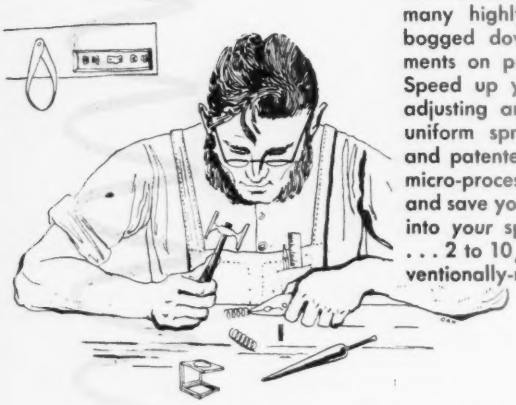

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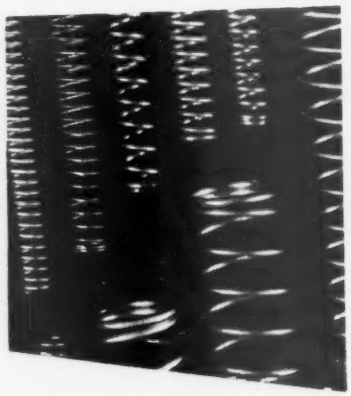

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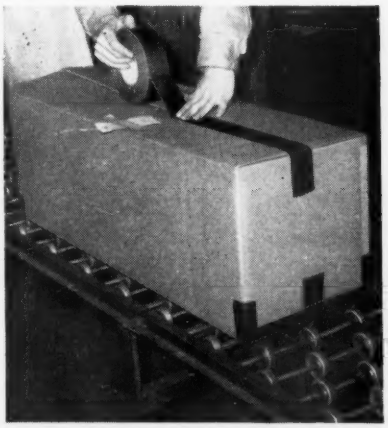

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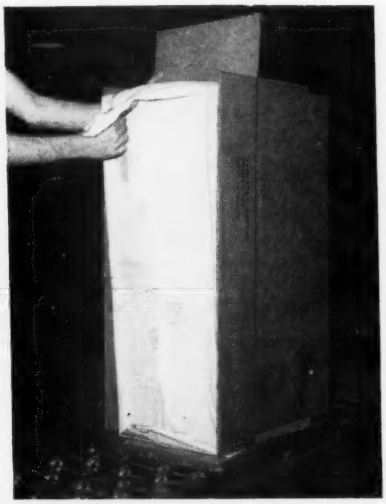

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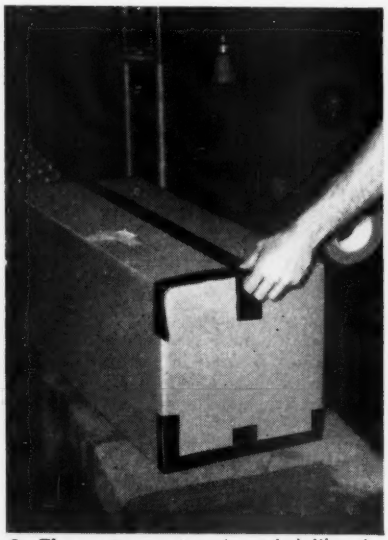

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problem and the buckling problem, based on the energy equation.

Readers' Forum: Prestressing Rectangular Thin Plates to Increase Their Buckling Loads. Chi-Teh Wang, Arthur L. Ross, and Edward L. Reiss, *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 568, 569, illus. 4 references.

Readers' Forum: Comments on "Remarks on Dynamic Loads in Landing" by Adam Zahorski. E. H. Kramer. *Journal of the Aeronautical Sciences*, Vol. 19, No. 8, August, 1952, pp. 572, 573.

Soap Film Technique for Solving Torsion Problems. Ken Ikeda. *Japan Science Review*, Vol. 2, No. 2, August, 1951, pp. 113–118, illus. 4 references.

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Mapping Techniques Applied to Fluid Mapper Patterns. A. D. Moore. *Electrical Engineering*, Vol. 71, No. 5, May, 1952, p. 446, illus. 4 references.

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A summary of nine papers, delivered at the 5th Annual Conference of the Stress Analysis Group of the Institute of Physics, Liverpool, April 4–6, 1951, on numerical methods, electric resistance strain-gage methods, French developments, and fatigue and photoelastic work.

Thermodynamics (18)

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The Contribution of Radiation to the Conduction of Heat. E. F. M. van der Held. *Applied Scientific Research, Section A, Mechanics, Heat, Chemical Engineering, Mathematical Methods*, Vol. 3, No. 3, 1952, pp. 237–249, illus. 3 references.

Development of a nonstationary method for measuring thermal conductivity; the method consists of applying electric heat to a wire that is stretched out in the material and measuring the temperature close to the wire thermoelectrically.

Gas Cooling of a Porous Heat Source. Leon Green, Jr. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 173–178, illus. 15 references.

Analysis of a limiting case of heat removal from a porous wall by a gaseous coolant when the surface per unit volume of the porous structure is high enough that the fluid temperature at any point may be considered to be the same as that of the adjacent solid; calculations for a heated graphite wall cooled by helium; temperature-stability problems; sweat-cooling for high-pressure, high temperature ducts.

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Jet Heat Exchangers Made Lighter. *Aviation Week*, Vol. 56, No. 23, June 9, 1952, pp. 58, 60, 61, illus.

Techniques of producing lightweight aluminum heat exchangers in various configurations to fill a wide range of gas-to-gas, liquid-to-liquid, and gas-liquid heat-transfer requirements for jet aircraft and other applications, developed by Trane Co.

Design of Apparatus for Determining Heat Transfer and Frictional Pressure Drop of Nitric Acid Flowing Through a Heated Tube. Bruce A. Reese and Robert W. Graham, *U.S., N.A.C.A., Research Memorandum, No. 52D03*, June 16, 1952. 61 pp., illus. 18 references.

Heat-Exchanger Tube-Sheet Design. II—Fixed Tube Sheets. K. A. Gardner. *Journal of Applied Mechanics*, Vol. 19, No. 2, June, 1952, pp. 159–166, illus. 3 references.

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The Future of the Flying Boat. Henry Knowler. (5th Louis Blériot Lecture, Paris, March 12, 1952.) *Royal Aeronautical Society, Journal*, Vol. 56, No. 497, May, 1952, pp. 322–352, illus.

Outline of the historical development of the flying boat; contemporary types; new technical developments; possible future developments in civil, military, and commercial types.

Boeing 314 Clipper Four-Engined Transoceanic Flying Boat (Speeds and Normal Accelerations of Boeing Clipper Aircraft on North and South Atlantic Routes). D. T. Jones. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2633*, 1952 (May, 1948). 14 pp., illus. 5 references. British Information Services, New York. $1.00.

Results obtained from V-g recorders fitted to Boeing Clipper aircraft between September, 1944, and May, 1946, and covering about 3,300 flying hours with a maximum speed of 215 m.p.h. (I.A.S.) and maximum accelerations of 2.3g upward and $-0.3g$ downward.

Some Studies of the Impact of Vee Wedges on a Water Surface. R. L. Bisplinghoff and C. S. Doherty. *Franklin Institute, Journal*, Vol. 253, No. 6, June, 1952, pp. 547–561, illus. 11 references.

Study of seaplane impact loads; review of the background and present status of two-dimensional vee-wedge theory; verification of existing theories by two-dimensional experiments; derivation of a formula for the shape of the free-water surface.

M-270 Hull Reduces Flying Boat Drag. *Aviation Week*, Vol. 56, No. 25, June 23, 1952, pp. 34, 37, 38, illus.

Construction, tank and wind-tunnel test results, and evaluation of the M-270, a full-scale flying boat hull model with a length-beam ratio of 15, which was developed by The Glenn L. Martin Co. to reduce the aerodynamic drag.

Wind Tunnels & Research Facilities

Current Projects in Aerodynamics Laboratory, Aircraft and Allied Instrument Laboratory, Engine Laboratory, Engineering Section, Flight Research Section, Fuels and Lubricants Laboratory, Gas Dynamics Section, Low Temperature Laboratory, and Structures Laboratory. *Canada, National Research Council, Aeronautical Laboratories, Quarterly Bulletin, Report No. NAE 1952 (1)*, January 1–March 31, 1952, pp. 6–25, illus.

Forrestal Center to Study Fundamentals. David A. Anderton. *Aviation Week*, Vol. 56, No. 25, June 23, 1952, pp. 21, 23, 25, 26, illus.

Research on supersonic flow, jet propulsion, boundary-layer control and stabilization systems, and helicopters undertaken at the James Forrestal Research Center of Princeton University; equipment and laboratories.

Activities of the Geophysics Research Division, Air Force Cambridge Research Center (AFCRC). H. E. Landsberg. *Weatherwise*, Vol. 5, No. 3, June, 1952, pp. 55–58, illus.

Rocket Model Does Work of Windtunnel. George L. Christian. *Aviation Week*, Vol. 56, No. 23, June 9, 1952, pp. 21, 22, 24, 25, illus.

Construction, instrumentation, and operation of a rocket-powered vehicle that carries a scale-model tailless delta-type fighter wing and telemetering equipment, and provides accurate flight information less expensively than wind-tunnel tests.

Condensation of Air in Supersonic Wind Tunnels and Its Effects on Flow About Models. C. Frederick Hansen and George J. Nothwang. *U.S., N.A.C.A., Technical Note No. 2690*, April, 1952. 49 pp., illus. 23 references.

Theoretical and experimental study of condensation phenomena, using data obtained in the N.A.C.A. Ames 10- by 14-in. supersonic wind tunnel and a 1- by 1.4-in. supersonic nozzle; possibility of extending the Mach Number range of condensation-free flow by achieving a relatively stable supersaturated state; effect of condensation on the flow about models, and on the accuracy of data obtained from such models.

An Experimental Investigation of the Performance of a Pilot Plant for Drying Air by Solid Granular Adsorbents. P. J. Bateman. *Gt. Brit., Aeronautical Research Council, Current Papers*

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No. 79, 1952 (February, 1951). 43 pp., illus., folding charts. 9 references. British Information Services, New York. $1.50.

Measurement of the performance on a pilot-plant scale of uncooled beds of two grades of activated alumina and one of silica gel in a $2^1/_2$- by $2^1/_2$-ft. bed at depths varying between 12 and 25 in. for drying air to the low humidities required for supersonic wind-tunnel operation.

Tunnel Blockage near the Choking Condition. A. Thom and Myra Jones. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2385*, 1952 (August, 1946). 16 pp., illus. 23 references. British Information Services, New York. $1.15. Theory of two methods for estimating solid blockage; estimation of blockage corrections up to the choking speed of the tunnel.

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Experimental data on tests of corner vanes (mainly thin curved plates) in a 1-ft. square wind tunnel to determine whether, and to what extent, these vanes would be suitable as turning vanes for the corners of return-flow tunnels. Tests were made on thin vanes at deflections of 45° and 90° and wind speeds of 100 and 90 ft. per sec. respectively, and on Collar vanes with splitters at 90° deflection and a speed of 90 ft. per sec.

Strain-Gage Balance Measures Drag Force. *Electronics*, Vol. 25, No. 6, June, 1952, p. 156, illus.

Construction and operation of an electronic strain-gage balance that obtains precise measurements of the drag force acting on supersonic wind-tunnel models at the Naval Ordnance Laboratory, White Oaks, Md.

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METEOROLOGY

The Upper Atmosphere. S. K. Mitra. 2nd Ed. (The Asiatic Society, Monograph Series, Vol. 5.) Calcutta, The Asiatic Society, 1952. 713 pp., illus. diagrs., figs. Rupees 48.

The aim of this treatise is to give an account of the present state of knowledge of the upper atmosphere as it has been obtained by direct and indirect observations. The first edition was published in 1948. In the new edition, extensive revisions have been made, and a number of new matters have been added to bring the book up to date. Some of the important additions are: atomic nitrogen in the upper atmosphere, radar study of meteors, the phenomenon of "sudden phase anomaly" in long-wave ionospheric reflection, the Huancayo anomaly in diurnal geomagnetic variations, winds and tides in the ionosphere, and a chapter on rocket explorations of the upper atmosphere.

Eighty-two illustrations have been added, and the bibliography has been expanded to include more than 1,000 references. There is an 8-page index of authors referred to in the text and in the bibliography, and a 37-page index of subjects. In the Appendix, a new section on proposed upper atmospheric nomenclature has been added. Professor Mitra is associated with the Institute of Radio Physics and Electronics, University College of Science, Calcutta.

PRODUCTION

Production Control. Paul D. O'Donnell. New York, Prentice-Hall, Inc., 1952. 304 pp., figs. $6.35.

This book has been prepared as a basic text for those desiring an elementary knowledge of production control. Highly technical and specialized applications have purposely been omitted. General consideration is given to the various phases of production control, which are later applied to continuous-process companies and job companies. To indicate the effect of other factors in company operations, several cases are given at the ends of most chapters which show the procedures and problems of various companies. There are some footnote references, a list of books for further reading, and an index of subjects. The author is Assistant Professor of Industrial Management, Boston College.

Contents: 1, Introduction. 2, Production Forecasting. 3, Product Development. 4, Plant Layout. 5, Materials Handling. 6, Control of Materials. 7, Routing. 8, Scheduling. 9, Dispatching. 10, Follow-up. 11, Quality Control. 12, Statistical Quality Control. 13, Cost Control.

REFERENCE WORKS

Aircraft Engines of the World 1952. Paul H. Wilkinson. New York, Paul H. Wilkinson, 1952. 320 pp., illus. $12.

Now in its tenth edition, *Aircraft Engines of the World* has been brought up to date as of April 30, 1952. As in previous years, the data are presented in standardized form. The Jet Engines and Gas Turbines section now occupies 132 pages. The introduction describes the progress made in main and auxiliary power plants in America and Europe, including the U.S.S.R. Important accessories for these engines are mentioned, and data on 40 turbojets, 12 turbojets with afterburners, and 15 turboprops are tabulated. Complete specifications of 60 jet engines are presented in standardized page form, of which 13 are new and many have been rewritten. Important auxiliary turbines are included. The Jet Aircraft and Their Engines section, now expanded to five pages, lists 192 of the latest aircraft, including 20 of the Soviet Union. The section on reciprocating engines contains 138 pages and standardized descriptions of 66 reciprocating engines. A tabulation of 13 helicopter engines is included. The book concludes with a revised table of Aviation Fuels and Lubricants and an alphabetic index to the engine descriptions.

Statistical Handbook of Civil Aviation, 1950. U.S., Civil Aeronautics Administration, 1952. Washington, Superintendent of Documents, 1952. 115 pp., charts. $0.50.

The present, fifth edition follows the same plan as the 1949 volume and contains all available civil statistics through December, 1950. Unlike previous editions, this edition does not contain data on military production.

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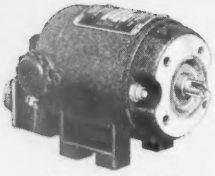

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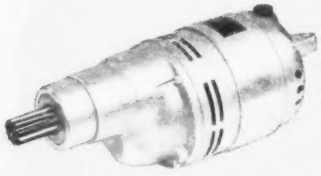

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Mechanical Engineers—Army Ordnance Design. Engineering ability to make original layouts and calculations required in the design of aircraft and ground-type rocket and missile launchers, aircraft and ground-type artillery and small arms weapons, and the mechanisms and control units involved, such as hydraulic and electrical power systems, structural elements, linkages, cams, gear trains, etc. GS-11, $5,940 per annum—bachelor degree plus $2\frac{1}{2}$ years' progressive professional engineering experience, including at least 6 months of difficult and important work in the appropriate branch of engineering equivalent in grade level to that required of GS-9 engineers; GS-9, $5,060 per annum—degree plus $1\frac{1}{2}$ years of progressive professional engineering experience, including at least 6 months' work in the appropriate branch of engineering equivalent in grade level to that required of GS-7 engineers; GS-7, $4,205 per annum—degree plus 6 months of professional engineering experience in the appropriate branch of engineering. Lacking degree, combination of education and experience permitted. Applicants should submit Standard Form 57, Application for Federal Employment (available at any Post Office), to: Personnel Division, Rock Island Arsenal, Rock Island, Illinois.

Mechanical Engineers—The advent of the flush deck carrier and the high-performance jet aircraft produces new and exciting challenges in the field of catapult design. This is an expanding field where new ideas and original work will bear their mark on the future of Naval aviation. The Bureau of Aeronautics, accordingly, is seeking the services of qualified mechanical engineers with 3–10 years' experience for positions paying $5,000 to $8,000 per annum. Applicants should have a thorough knowledge of mechanics, structures, and thermodynamics. Those selected will be required to represent the Bureau of Aeronautics with contractors and other Government activities and, therefore, should possess a high degree of executive talent. Applicants should submit Standard Form 57, Application for Federal Employment (available at any Post Office), to Department of the Navy, Bureau of Aeronautics, Personnel Division, Attention PE-22, Washington 25, D.C.

Aeronautical Engineers—Vacancies for aeronautical engineers exist in the Bureau of Aeronautics, Department of the Navy, Washington, D.C. Aerodynamic development engineers (performance) GS-11, $5,940 per annum; GS-9, $5,060 per annum; GS-7, $4,205 per annum; and GS-5, $3,410 per annum. Analysis and evaluation of performance characteristics of new aircraft designs, experimental and service type aircraft and proposed modifications thereto, including interpretation and application of results of laboratory tests affecting aircraft performance. Applicants should submit Standard Form 57, Application for Federal Employment (available at any Post Office), to Department of the Navy, Bureau of Aeronautics, Personnel Division, Attention PE-22, Washington 25, D.C.

Engineers—The U.S. Naval Air Rocket Test Station has several vacancies in the Engineering Department. **Chemical Engineer**—GS-12, $7,040 per annum. Duties: Head of the Special Projects Branch, Propellants Division, Engineering Department. Directs specialized investigations into the problems of combustion of solid and liquid propellants in rocket engines, determination of physical and thermodynamic properties of propellants, studies of corrosion of materials by propellants. **Aeronautical Engineer (Power Plants)**—GS-12, $7,040 per annum. Duties: Head of Evaluation Branch, Power Plants Division, Engineering Department. Directs specialized investigations of the performance, durability, and reliability of solid- and liquid-propellant rocket engines, power plants, and components. Prepares progress and summary reports. **General Engineer**—GS-11, $5,940 per annum. Duties: Head of Facilities Branch, Power Plants Division, Engineering Department. Directs the preparation of plans, procurement and installation of new rocket test facilities and equipment, and the modification of existing facilities and equipment as required for specialized tests. **General Engineer**—GS-9, $5,060 per annum. Duties: Project Engineer in the Facilities Branch, Power Plants Division, Engineering Department. Makes plans, procures and installs facilities and equipment for the testing of rockets and components. **Chemical Engineer**—GS-9, $5,060 per annum. Duties: Project Engineer in the Special Projects Branch, Propellant Division, Engineering Department. Conducts specialized investigations into the problems of combustion of solid and liquid propellants in rocket engines, determination of physical and thermodynamic properties of propellants, studies of materials for storage and handling of propellants. Prepares reports. **Aeronautical Engineer (Power Plants)**—GS-9, $5,060 per annum. Duties: Project Engineer in the Evaluation Branch, Power Plants Division, Engineering Department. Conducts specialized investigations of the performance of solid- and liquid-propellant rocket engines, their components, and accessories. Prepares project reports for supervisor. **Aeronautical Engineer (Power Plants)**—GS-7, $4,205 per annum. Duties: Test Engineer in the Test Branch, Power Plants Division, Engineering Department. Devises test procedures and conducts tests of rocket engines, components, and accessories. Makes performance calculations, prepares reports. **Illustrator (Equipment)**—GS-6, $3,795 per annum. Duties: Illustrator in the Technical Publications Branch of the Engineering Department. Makes original illustrations of mechanical equipment and layout of illustrations, photographs, and title pages for technical reports. **Chemist**—GS-5, $3,410 per annum. Duties: junior chemist in the Chemistry Branch, Propellant Division, Engineering Department. Performs quantitative and qualitative analysis of solid and liquid fuels and oxidizers. Assists senior chemist in specialized investigations of chemical properties of propellants and handling materials. Applicants should complete Standard Form 57, Application for Federal Employment, which is available at any Post Office, and forward to the Industrial Relations Officer, Industrial Relations Department, U.S. Naval Air Rocket Test Station, Lake Denmark, Dover, N.J.

Scientists and Engineers—Needed for responsible positions in the technical development and production of solid propellants and rocket units. There are good opportunities in this long-range program for those with experience in chemistry, quality control, and processing or unit design of solid-propellant manufacture. Please give a complete résumé of your education and past experience. All replies held strictly confidential. Write Industrial Relations Manager, Research and Development Department, Phillips Petroleum Company, Bartlesville, Okla.

421. Aeronautical Engineer—Opening for instructor in airplane design and related subjects in aeronautical engineering curriculum. Excellent opportunity for qualified man. Reply should cover engineering education and experience. California location (Los Angeles area).

415. Instructor—Aeronautical Engineering Department of a large eastern university to teach undergraduate courses in fluid mechanics and aeronautical laboratory. Applicant should have master's degree from recognized university or equivalent experience in the aeronautical field. Opportunity for graduate work and research in structures or aerodynamics. Large subsonic and 6-in. supersonic tunnels in operation. Salary $4,000 for the academic year.

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Available

437. Sales Engineer—Seven years' aircraft experience. Presently contacting power-plant, equipment, and electrical groups of all major eastern air-frame and helicopter concerns and Government agencies. Aircraft experience includes engineering and sales in manufacture, service, and instrumentation. M.E. background. Pilot; married. Relocating on East Coast in October.

430. Aeronautical Engineer—B.S. in Ae.E., M.Ae.E. Desires position that presents challenging and diversified activity, contact with various phases of the aeronautical field, and opportunity for advancement through merit. Capable of directing and coordinating work of small group. Experienced in research analysis, technical writing, and public speaking. Meets people easily; wide range of interests. Five years' experience with top Government research

agency. Presently employed as project engineer in wind tunnel section. Age 26; married. Complete personal résumé sent on notification of available openings.

429. Aeronautical Engineer—B.S. in Ae.E., N.Y.U., 1946. Six years' experience with U.S. air line covering aircraft repair, weight and balance, flight test, performance, design of power and performance charts, operations manual, DC-3, DC-4, DC-6, and DC-6B operating manuals, etc. Also complete advanced training in meteorology at N.Y.U. and University of Chicago Institute of Tropical Meteorology. Speaks and writes Spanish and French fluently. Latin American nationality. Seeks aeronautical position either in the United States or abroad.

427. Aeronautical Safety Engineer—Desires position with aircraft manufacturer offering responsible duties in evaluation of specific safety functional problems in design and experimental stages. Served 6,400 hours' structural layout apprenticeship, equivalent to 2 years of intensive college studies. Private pilot's license; single- and twin-engine experience, approximately 1,800 hours. Technical writer of safety consciousness in aircraft design. Former owner and chief engineer of small aircraft company in Midwest. Fourteen years' varied aircraft and complex machine design. Age 36.

423. Sales Engineer and Technical Representative—Internationally known engineer, with exceptional entree to all aircraft activities on the Pacific Coast, will represent East Coast or Midwest manufacturer. Thoroughly familiar with all aircraft components, instruments, etc. Headquarters, Los Angeles.

422. Aeronautical Engineer (Flight Test)—B.S.Aero.E. Four years' experience as flight-test and aerodynamic engineer. Background of progressive experience in various phases of aircraft performance, stability and control, and component test work. Desires position in flight-test or aerodynamic research. Location open. Available November, 1952.

420. Engineer—B. of M.E., Gas Turbine Project Engineer in Government for 1 year. Previous engineering background in aircraft tooling, welding, and process planning for 2 years. Also practical experience as toolmaker. Desires permanent position of increasing responsibility in gas-turbine or allied industry. Age 29.

419. Aeronautical Engineer—M.E. and M.S. 23 years' experience with large aircraft companies in all phases of stress analysis, aerodynamics, flight testing, and dynamics analysis. Would like connection with small aircraft concern in executive or staff capacity in charge of similar type of work.

418. Research and Development Engineer—Extensive background. Would like to consult on aerodynamic instrumentation for wind tunnel, flight test, and ballistics of missiles and rockets. Has made significant developments. Design, construction, and testing of prototypes can be furnished.

417. Independent Engineer—With many years' experience in aeronautics and research. Would like to contact progressive organization with product, idea, or territory available for Southern California or perhaps West Coast. Wide contacts and background in aircraft, guided missile, rocket and ballistics engineering, and research circles. Can provide staff or organization for sales, engineering, consulting, or technical representation.

414. Engineering or Research Executive—Many years' experience with leading company. Offering an outstanding record in design and research, allied to demonstrated administrative ability. Familiar with subsonic and supersonic design. Airplanes, missiles, dynamic problems, guidance, servomechanisms, and flight testing.

412. Aero Mechanical Engineer—B.M.E.; age 33. Eleven years' experience in the aircraft industry comprising guided missile electromechanical systems development, flight-test research, and stress analysis. Three most recent years in supervision as assistant project electromechanical engineer and project test engineer. Experience includes directing electrical system design, environmental-test program, booster rocket installation design, test equipment design, and flight-test programs. Familiar with military specifications. Seeking supervisory or administrative position in aircraft, missile, or allied field in New York City area only. Will furnish résumés upon request. Please indicate nature of available positions in first letter.

410. Aeronautical Engineer—(B.S. 1948). Age 25, single. Currently serving in Army under Special Professional Personnel Program. Army experience: Eight months with Project Investigation Section, Ordnance Guided Missile Center, aided in developing nomograms for first approximations of missile performance. Twelve months with Army Aircraft National Maintenance Point; helped establish procedures for use of IBM equipment in the preparation of Army Supply Catalogs and helped to develop procedures for maintenance of Army liaison aircraft and helicopters. Civilian experience includes 18 months' power-plant installation design, 6 months' flight-test work. Has private pilot's license, Aircraft and Engine Mechanic's ratings. Would like position with small, expanding company, preferably in the guided missile or helicopter fields. Available January 1, 1953.

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